OXFORD IB DIPLOMA PROGRAMME

# ENVIRONMENTAL SYSTEMS AND SOCIETIES

2015 EDITION

COURSE COMPANION


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OXFORD

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## About the authors

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# 1 FOUNDATIONS OF ENVIRONMENTAL SYSTEMS AND SOCIETIES

## 1.1 Environmental value systems

### Significant ideas:

- Historical events, among other influences, affect the development of environmental values systems and environmental movements.
- There is a wide spectrum of environmental value systems each with their own premises and implications.

### Applications and skills:

- **Discuss** the view that the environment can have its own intrinsic value.
- **Evaluate** the implications of two contrasting environmental value systems in the context of given environmental issues.
- **Justify** the implications using evidence and examples to make the justification clear.

### Knowledge and understanding:

- Significant historical influences on the development of the environmental movement have come from literature, the media, major environmental disasters, international agreements and technological developments.
- **An environmental value system (EVS) is a worldview or paradigm that shapes the way an individual, or group of people, perceives and evaluates environmental issues**, influenced by cultural, religious, economic and socio-political contexts.
- An EVS might be considered as a 'system' in the sense that it may be influenced by education, experience, culture and media (inputs) and involves a set of inter-related premises, values and arguments that can generate consistent decisions and evaluations (outputs).
- There is a spectrum of EVSs from ecocentric through anthropocentric to technocentric value systems.
- **An ecocentric viewpoint** integrates social, spiritual and environmental dimensions into a holistic ideal. It **puts ecology and nature as central to humanity** and emphasizes a less materialistic approach to life with greater self-sufficiency of societies. An ecocentric viewpoint prioritizes biorights, emphasizes the importance of education and encourages self-restraint in human behaviour.
- **An anthropocentric viewpoint argues that humans must sustainably manage the global system.** This might be through the use of taxes, environmental regulation and legislation. Debate would be encouraged to reach a consensual, pragmatic approach to solving environmental problems.
- **A technocentric viewpoint argues that technological developments can provide solutions to environmental problems.** This is a consequence of a largely optimistic view of the role humans can play in improving the lot of humanity. Scientific research is encouraged in order to form policies and understand how systems can be controlled, manipulated or exchanged to solve resource depletion. A pro-growth agenda is deemed necessary for society's improvement.
- There are extremes at either end of this spectrum (eg deep ecologists – ecocentric – to cornucopian – technocentric), but in practice EVSs vary greatly with culture and time and rarely fit simply or perfectly into any classification.
- Different EVSs ascribe different intrinsic values to components of the biosphere.

**TOK**

1. Using a global environmental issue of your choice evaluate how one of the ways of knowing influences our EVS approach.
2. Using a local environmental issue of your choice evaluate how one of the ways of knowing influences our EVS approach.
3. Evaluate how your emotion has affected your response to this issue.

**Key term**

An **environmental value system (EVS)** is a worldview or paradigm that shapes the way an individual or group of people perceive and evaluate environmental issues. This will be influenced by cultural, religious, economic and socio-political context.

**To think about**

Our environmental value systems will influence the way we see environmental issues.

1. List other value systems that influence how we view the world.
2. Outline one named global and one local environmental issue.

Describe your opinion on these issues and explain how your value systems influence it.

*'Whatever befalls the Earth – befalls the sons of the Earth.*

*Humankind has not woven the web of life. We are but one thread within it. Whatever we do to the web, we do to ourselves. All things are bound together. All things connect.'*

Attributed to Chief Seattle, 1855

**Figure 1.1.1** The only known photo of Chief Seattle taken in the 1860s

## Development of the environmental movement

The environmental movement as we know it originated in the 1960s BUT humans have been concerned about the effect we have on the environment for much longer.

- Romans reported on problems such as air and water pollution.
- Between the late 14th century and the mid 16th century, waste produced by humans was associated with the spread of epidemic disease in Europe.
- Soil conservation was practised in China, India and Peru as early as 2,000 years ago.

Such concerns did not really give rise to widespread public activism until recently. To understand modern environmentalism we must look back at the historical events which:

- caused concern over environmental impacts
- elicited the responses of individuals, groups of individuals, governments and the United Nations to these impacts.

Powerful individuals and independent pressure groups are now very influential though their use of media, and they have catalysed the movement to make it a people's or 'grass roots' movement. There has also been a continuing divide in philosophy between:

- those who see the reason for conserving nature as being to continue to supply goods and services to humankind in a sustainable way (environmental managers) and
- those who believe that we should conserve nature unconditionally, for its spiritual value (deep and self-reliance ecologists);

  ie do we save it for **our** sake or for **its** sake?

## Who is involved in the environmental movement?

It is probably fair to say that the majority of people in the world do not spend much time focusing on environmental issues unless they are brought to their attention or affect them directly. However, the activities of a number of groups have influenced

- norms of behaviour (eg purchasing choices such as dolphin-friendly tuna and recycling) and
- political choices (eg the successes of the 'Green Party').

**Influential individuals** often use media publications (eg Aldo Leopold's *A Sand County Almanac,* Rachel Carson's *Silent Spring,* Al Gore's *An Inconvenient Truth*) to raise issues and start the debate.

**Independent pressure groups** use awareness campaigns to effect a change (eg Greenpeace on Arctic exploration, World Wildlife Fund on saving tigers). They influence the public who then influence government and corporate business organizations. These groups are called non-governmental organizations (NGOs). 'Friends of the Earth' is another example.

**Corporate businesses** (especially multinational corporations – MNCs – and transnational corporations – TNCs) are involved since they are supplying consumer demand and in doing so using resources and creating environmental impact (eg mining for minerals or burning of fossil fuels).

**Governments** make policy decisions including environmental ones (eg planning permission for land use), and apply legislation (laws) to manage the country (eg emissions controls over factories). They also meet with other governments to consider international agreements (eg United Nations Environment Programme, UNEP). Different countries are at different stages of environmental awareness, as are different individuals. Legislating about emissions is important but so is making sure there is enough food for the population. While different countries may put environmental awareness at different levels of priority, all are aware of the issues facing the Earth and that all must be involved in finding solutions.

**Intergovernmental bodies** such as the **United Nations** have become highly influential in more recent times by holding Earth Summits to bring together governments, NGOs and corporations to consider global environmental and world development issues.

### TOK

In 2013, 30 Greenpeace activists on board the Greenpeace ship *Arctic Sunrise* peacefully protested in Arctic international waters against the Russian Gazprom oil platform drilling for oil in the Arctic. They were arrested by armed Russian commandos and kept in prison for 100 days before being freed.

Read about this at www.greenpeace.org and news websites.

Do you agree with what the activists were doing or do you agree with the Russian authorities in stopping them?

Debate the issues in this with three teams: one represents Greenpeace views, one the Russian state and the other the Gazprom interests.

To what extent can we rely on reason to evaluate the Greenpeace approach to this issue?

### To research

Look up Chief Seattle on the web. His famous speech was in the Lushootseed language, translated into Chinook Indian trade language, and then into English. While he may not have said these exact words, does it matter?

***'We abuse land because we regard it as a commodity belonging to us. When we see land as a community to which we belong, we may begin to use it with love and respect.'***

Aldo Leopold,
*A Sand County Almanac*
(reprinted by permission of Oxford University Press, USA)

**The growth of the modern environmental movement in outline**

| Event | Impact |
|---|---|
| **Neolithic Agricultural Revolution (10,000 years ago)** | • Humans settled to become farmers instead of nomadic hunter-gatherers<br>• Human population began to rise<br>• Local resources (food, water, fuel) were managed sustainably from around the settlement |
| **Industrial Revolution (early 1800s)** | • Population growth and resource usage escalated<br>• Large scale production of goods and services for all<br>• Burning of large amounts of fuel in the form of trees and coal<br>• Mining of minerals from the earth to produce metals to make machines<br>• Limestone quarried for cement production<br>• Land was cleared, natural waterways polluted, cities became crowded and smoky<br>• Our urban consumer society arose |
| **Green Revolution of the 1940s to 1960s** | • Mechanized agriculture and boosted food production massively<br>• Required the building of machinery and burning of enormous amounts of fossil fuels such as oil<br>• Technology was applied to agriculture<br>• New crop varieties were developed and fertilizer and pesticide use rose sharply<br>• The world population grew to about 3 billion<br>• Our resource use and waste production rocketed |
| **Modern environmental movement**<br>**(1960s onwards)** | • The impacts became more global: collapsing fish stocks, endangered species, pesticide poisoning, deforestation, nuclear waste, ozone layer depletion, global warming, acid precipitation, etc.<br>• A new breed of **environmentalists** surfaced who had scientific backgrounds and spearheaded the modern environmental movement<br>• Greenpeace founded 1971<br>• Influential individuals wrote books (eg Rachel Carson's *Silent Spring*)<br>• NGOs campaigned and the media reported<br>• Governments formed nature reserves and put environmental issues on their agenda<br>• Some businesses marketed themselves as environmentally friendly<br>• UNEP organized Earth Summits on the environment<br>• The movement became public and gained momentum |
| **Environmentalism today** | • More research on loss of biodiversity and climate change leading to more action to protect the environment and encourage sustainability from governments, corporations and individuals<br>• Small number of climate sceptics voice doubts over climate change<br>• Discovery of fracking process to release shale gas and oil shale reserves increases tensions between technocentrists and ecocentrists |

*'And this is why I*
*sojourn here,*
*Alone and palely loitering,*
*Though the sedge is wither'd*
*from the lake,*
*And no birds sing.'*

From *La Belle Dame Sans Merci* by John Keats

## Case studies – historical influences on the environmental movement

There is general agreement that the modern environmental movement was catalysed by Rachel Carson's book, *Silent Spring*, published in 1962. The title comes from the John Keats poem (right). Carson warned of the effects of pesticides on insects, both pests and others, and how this was being passed along the food chain to kill others, including birds (hence a silent spring). What really gained people's attention was her belief that pesticides such as DDT (**d**ichloro**d**iphenyl**t**richloroethane, a persistent, synthetic insecticide) were finding their way into people and accumulating in fatty tissues, causing higher risks of cancer. Chemical industries tried to ban the book but many scientists shared her concerns and when an investigation, ordered by US president John F. Kennedy, confirmed her fears, DDT was banned.

*'For the first time in the history of the world, every human being is now subjected to contact with dangerous chemicals, from the moment of conception until death.'*

Rachel Carson, *Silent Spring*, 1962

In the decades since the publication of *Silent Spring*, it has been criticized as scaremongering without enough scientific evidence. The banning of DDT may have caused more harm than good (see 2.2) by allowing the mosquitoes that carry malaria to survive and so spread the disease causing millions of deaths.

Al Gore, former US vice-president, was heavily influenced by the book to become involved in environmental issues, particularly with his documentary on climate change *An Inconvenient Truth,* 2006. This raised awareness of climate change – then called global warming – and clearly stated that global climate change was a result of greenhouse gases released by human activities and that we had to act as this is a moral issue. George Bush's response to the documentary when he was president of the USA was 'Doubt it' and he later said that we should focus on technologies that enable us to live better lives and protect the environment.

*'Now I truly believe that we in this generation must come to terms with nature, and I think we're challenged, as mankind has never been challenged before, to prove our maturity and our mastery, not of nature but of ourselves.'*

Rachel Carson, *Silent Spring*, 1962

Mercury is a heavy metal and is poisonous to animals. It affects the nervous system causing loss of vision, hearing and speech and lack of coordination in arms and legs. Severe poisoning causes insanity or death. Mercury was used in the hat-making industry into the 20th century. Hat makers were known to often suffer mental illnesses although the source of such illnesses was unknown. This is the basis of the name of the 'Mad Hatter' character in Lewis Carroll's *Alice in Wonderland* and the phrase 'mad as a hatter'.

The Chisso Corporation built a chemicals factory in Minamata, Japan and was very successful for years. But a by-product was methylmercury which bioaccumulated in the bodies of humans, causing mercury poisoning (see 2.2).

In the early hours of the morning of 3 December 1984, in the centre of the city of Bhopal, India, in the state of Madhya Pradesh, a Union Carbide pesticide plant released 40 tonnes of methyl isocyanate (MIC) gas, immediately killing nearly 3,000 people and ultimately causing at least 15,000–22,000 total deaths. This has been called the **Bhopal Disaster** and is considered to be the world's worst industrial disaster. The world was in shock.

In 1986, at **Chernobyl**, the worst nuclear disaster ever occurred. This was a few miles north of Kiev, the capital of Ukraine (then part of the USSR) where an explosion and then fire resulted in a level 7 event (the highest) in reactor number 4. The reactor vessel containing the uranium radioactive material split so exposing the graphite moderator to air which caused it to catch fire. The reactor went into uncontrollable meltdown and a cloud of highly radioactive material from this drifted over much of Russia and Europe as far west as Wales and Scotland. Fission products from the radioactive cloud, eg isotopes

**TOK**

Chernobyl has become synonymous with the dangers of nuclear power and the green political lobby argued that all nuclear power generation should stop. But nuclear reactor accidents are very rare and safety levels ever higher as new plants are developed.

More people are killed in car accidents or when shopping than by nuclear power accidents. Views about the rights and wrongs of using nuclear power are not based on evidence but on emotions. The rare accidents in nuclear power plants (Three Mile Island (Pennsylvania, USA in 1979), Chernobyl and Fukushima being the big ones) have resulted in some countries banning nuclear power generation. But our need for more and more energy may mean it has to be used.

To what extent do you think the arguments about nuclear power are based on emotion rather than reason?

of caesium, strontium and iodine, have a long half-life and were accumulated in food chains. In 2009, there were still restrictions on selling sheep from some Welsh farms due to their levels of radiation. There is much debate about how many people have been affected by the radiation as long-term effects, such as cancers and deformities at birth, are difficult to link to one event. 31 workers died of radiation sickness as they were exposed to high levels in trying to shut down the reactor and some had a lethal dose of radiation within one minute of exposure. Estimates of later deaths vary but some state about 1,000 extra cases of thyroid cancer and 4,000 other cancers caused by the fallout cloud. Other estimates state that 1 million people will have died as a result of the disaster.

The authorities of the day did not announce the disaster but it was picked up in Sweden when fallout was found on the clothing of workers at one of their nuclear plants.

Even today, the reactor is still dangerous. It was encased in a concrete shell but the other reactors continued to run until 2000. Now, a metal arch is being built as the concrete shell only has a lifetime of 30 years but estimates of the date of completion have been put back to 2016.

In 2011, there was another nuclear accident at the **Fukushima Daiichi** nuclear plant in Japan. An earthquake set off a tsunami which caused damage resulting in meltdown of 3 reactors in the plant. The water flooding these became radioactive and will take many years to remove. Although the radiation leak was only about 30% that of Chernobyl and radiation levels in the air low, one third of a million people were evacuated as the plant was sited in a densely populated area. Later reports showed the accident was caused by human error – it was not built to withstand a tsunami even though it was close to the sea in an earthquake zone. The plant is still not secured.

After the disaster, there were anti-nuclear demonstrations in other countries and Germany announced it was closing older reactors and phasing out nuclear power generation. France, Belgium, Switzerland all had public votes to reduce or stop nuclear power plants. In other countries, plans for nuclear plants were abandoned or reduced.

**Figure 1.1.2** The Chernobyl nuclear reactor plant after the explosion in 1986

## To research

1. Research these environmental disasters and write a short paragraph on each:

   Deepwater Horizon oil spill

   London smog

   Love Canal

2. Research these environmental movements and write a short paragraph on each:

   Chipko movement

   Rio Earth Summit and Rio +20

   Earth Day

   Green Revolution

   Kyoto Protocol

3. Research one local environmental disaster and one local environmental pressure group or society. Create an action plan for each to provide innovative solutions to the disaster and a 5-year plan for the environmental pressure group or society.

**A review of major landmarks in environmentalism**

| Years | Events | Significance |
|---|---|---|
| **10,000 yrs BP** | **Neolithic agricultural revolution** | Settlements, population increase, local resource management began. |
| **Early 1800s** | **Industrial revolution in Europe** | Increased urbanization, resource usage and pollution. |
| **Late 1800s** | **Influential individuals such as Thoreau and Muir write books on conservation** | First conservation groups form and nature reserves established. NGOs form (RSPB, NT). |
| **1914** | **Once the most prolific bird, the passenger pigeon becomes extinct** | Conservation movement grows. Concern for tigers, rhinoceros, etc. |
| **1930s and 1940s** | **Dustbowl in North America** | Recognition that agricultural practices may affect soils and climate. |
| **1940s** | **Green Revolution – intensive technological agriculture** | Resource use (especially fossil fuel use) and pollution increased. Human population rises sharply. |
| **1949** | **Leopold writes *'A Sand County Almanac'*** | Concept of 'stewardship' is applied to nature. |
| **1951** | **UK's ten National Parks are established** | Recognition of need to conserve natural areas. |
| **1956 to 1968** | **Minamata Bay Disaster** | Emphasizes the ability of food chains to accumulate toxins into higher trophic levels, including into humans. |
| **1962** | **Rachel Carson publishes *'Silent Spring'*** | General acceptance of dangers of chemical toxins affecting humans. The pesticide DDT is banned. |
| **1960s and early 1970s** | **NGOs gain greater following** | Public awareness grows.<br>WWFN, Greenpeace, Friends of the Earth all formed. |
| **1972** | **First Earth Summit – UN Conference on the Human Environment** | Declaration of UN conference.<br>Action Plan for the Human Environment.<br>Environment Fund established.<br>Formation of UN Environment Programme (UNEP).<br>Earth Summits planned at ten-year intervals. |
| **1975** | **C.I.T.E.S. formed by IUCN** | Endangered species protected from international trade. |

| | | |
|---|---|---|
| **Mid 1970s** | **Environmental philosophy established** | Recognition that nature has its own intrinsic value. Stewardship ethic grows. |
| **1979** | **James Lovelock publishes *'Gaia – A new look at life on Earth'* and presents the 'Gaia hypothesis'** | Systems approach to studying the environment begins. Nature seen as self regulating. |
| **1982** | **Nairobi Earth Summit** | Ineffective. |
| **1983** | **UN World Commission on Environment and Development publishes the Brundtland Report** | Sustainability established as the way forward. |
| **1984** | **Bhopal Disaster** | World's worst industrial disaster. |
| **1986** | **Chernobyl Disaster** | Nuclear fallout affects millions. |
| **Mid 1980s** | **British Antarctic Survey Team detects ice sheets thinning and ozone hole** | Public awareness of ozone depletion and risks of skin cancer. |
| **1987** | **Montreal Protocol** | Nations agree to reduce CFC use. |
| **1980s** | **Green political parties form around the world** | Political pressure placed on governments. |
| **1988** | **IPCC formed by UNEP** | Advises governments on the risks of climate change. |
| **1992** | **Rio Earth Summit and Kyoto Protocol** | Agreement to reduce carbon ($CO_2$) emissions to counter enhanced greenhouse effect and global warming.<br>Agenda 21. |
| **1990s** | **Green awareness strengthens** | Environmentally friendly products, recycling and ecotourism become popular. |
| **2002** | **Johannesburg Earth Summit** | Plans to globally improve:<br>Water and sanitation<br>Energy supply issues<br>Health<br>Agricultural abuse<br>Biodiversity reduction. |
| **2005** | **Kyoto protocol becomes a legal requirement** | 174 countries signed and are expected to reduce carbon emissions to some 15% below expected emissions in 2008. It expires in 2012. |
| **2006** | **Film *'An Inconvenient Truth'* released** | Documentary by Al Gore, former US vice-president, describing global warming. |
| **2007** | **Nobel Peace Prize**<br><br>**IPCC release 4th assessment report in Nov 07**<br><br>**UN Bali meeting Dec 07** | Awarded in 2007 jointly to Al Gore and the IPCC for their work on climate change.<br><br>Report states that 'Warming of the climate system is unequivocal' and 'Most of the observed increase in globally averaged temperatures since the mid-20th century is *very likely* due to the observed increase in anthropogenic greenhouse gas concentrations.'<br><br>187 countries meet and agree to open negotiations on an international climate change deal. |
| **2012** | **Rio +20** | Paper *'The Future We Want'* published. |

## To do

### Environmental headlines

9 March 2014 Lucy Hornby, Beijing in *Financial Times*

'Only three Chinese cities meet air quality standards'

11 March 2014 Suzanne Goldenberg, *The Guardian*

'California drought: authorities struggle to impose water conservation measures'

A. Look at newspaper headlines for one week.

   Copy out the headlines that refer to environmental issues.

   Put these in a table or on a notice board.

| Good news | Bad news |
|---|---|
| | |

B. Discuss with your fellow students what the environmental headlines may be in 2020 and 2050.

## To research

Look up these people who were involved in environmentalism and write three sentences on each.

| |
|---|
| Mahatma Mohandas Gandhi |
| Henry David Thoreau |
| Aldo Leopold |
| John Muir |
| E O Wilson |

## To do

Find a local environmental issue where a pressure group is fighting for a cause.

Describe the issue and state the argument of the pressure group. What are the opposing arguments to their case? These may be economic, aesthetic, socio-political or cultural. State your own position on this issue and defend your argument.

*'Nothing in this world is so powerful as an idea whose time has come.'*

Victor Hugo 1802–1885

## To do

### Earth Days

**This is just one of many images promoting Earth Day – what else can you find?**


In the late 1960s, after *Silent Spring*, environmentalism turned into action, particularly in North America. Founded then were 'Earth Days' to encourage us all to be aware of the wonder of life and the need to protect it. There are two different ones. The UN Earth Day each year is on the Spring equinox (so in March in the Northern hemisphere and September in the Southern when the Sun is directly above the equator). John McConnell, an activist for peace, drove this concept.

The other Earth Day is always on 22 April each year, and was founded by US politician Gaylord Nelson as an educational tool on the environment. Up to 500 million people now take part in its activities worldwide each year.

Some are critical of Earth Days as marginalized activities that do not change the actions of politicians. Do you think they have an effect?

## The spectrum of environmental value systems

- Different societies hold different environmental philosophies and comparing these helps explain why societies make different choices.
- The EVS we each hold will be influenced by cultural, religious, economic and socio-political contexts.
- The environment or any organism can have its own intrinsic value regardless of its value to humans. How we measure this value is a key to understanding the value we place on our environment.

For much of history, our viewpoint has been that the Earth's resources are unlimited and that we can exploit them with no fear of them running out. And for much of history that has been true. A much smaller human population in the past has been just one species among many. The words and phrases we use describe how we have seen the environment: 'fighting for survival', 'battle against nature', 'man or beast', 'conquering Everest', 'beating the elements'. It has only been in very recent times that humans have been able to control our environment and even think about terraforming (altering conditions to make it habitable for humans) on Mars. The Industrial Revolution heralded the arrival of the 'unbound Prometheus' of technological development when we were driven to explore, conquer and subdue the planet to the will of industrial growth. This ideology has reigned in the industrial world with the worldview that economic growth improves the lot of us all. But now it is clearer that the Earth's resources are not limitless as the Earth is not limitless. Humans may be the first species to change the conditions on Earth and so make it unfit for human life.

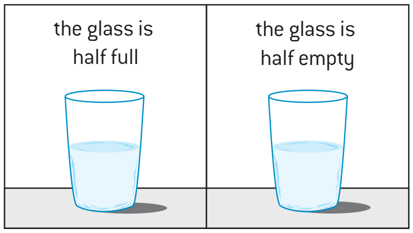



**Figure 1.1.3** Is this half full or half empty?

### What is your environmental worldview?

You have a view of the world that is formed through your experiences of life – your background, culture, education and the society in which you live. This is your paradigm or worldview. You may be optimistic or pessimistic in outlook – see the glass as half full or half empty.

**To do**

**Environmental attitudes questionnaire**

Consider these statements and decide if you agree strongly, agree, don't know, disagree or disagree strongly with each.

1. Humans are part of nature.
2. Humans are to blame for all the world's environmental problems.
3. We depend on the environment for our resources (food, water, fuel).
4. Nomadic and indigenous peoples live in balance with their environment.
5. Traditional farming methods do not damage the environment.
6. Nature will make good any damage that humans do to the Earth.
7. Humans have every right to use all resources on the planet Earth.
8. Technology will solve our energy crisis.
9. We have passed the tipping point on climate change and the Earth is warming up and we cannot stop it.
10. Animals and plants have as much right to live on Earth as humans.
11. Looking at a beautiful view is not as important as economic progress.
12. Species have always become extinct on Earth and so it does not matter that humans are causing extinctions.

Discuss your responses with your colleagues. Do they have different ones? Why do you think this is?

### TOK

Consider these words:

- Environment
- Natural
- Nature.

Think about what they mean to you. Write down your responses.

Now discuss what you wrote with two of your classmates. Do you agree?

What have you written that is similar or different?

Why do you think your responses may be different?

How different do you think the responses of someone from a different century or culture may be? Discuss some examples.

### TOK

**Our relationship with the Earth**

Can you think of other phrases that describe our relationship with nature and the Earth?

The words we use are often evaluative and not purely descriptive.

How do you think our language has influenced human perspectives on the environment?

How does the language we use influence your viewpoint?

## A classification of different environmental philosophies

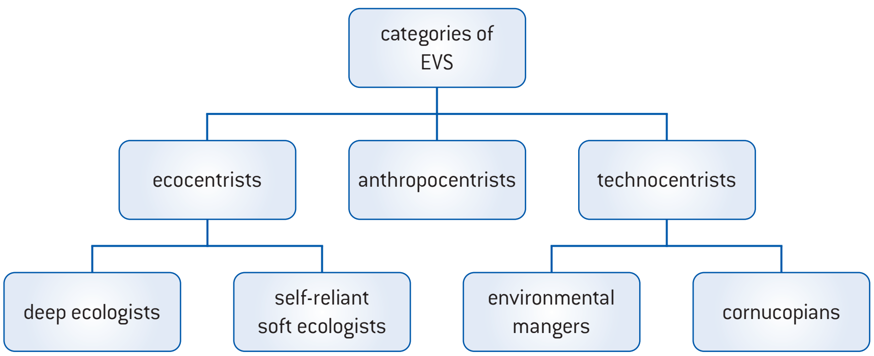



**Figure 1.1.4** EVS categories

Humans like to classify and categorize, and environmental philosophies are no exception to this. The major categories of EVSs are:

- The **ecocentric** worldview – **puts ecology and nature as central to humanity** and emphasizes a less materialistic approach to life with greater self-sufficiency of societies. Is life-centred – which respects the rights of nature and the dependence of humans on nature so has a holistic view of life which is earth-centred. Extreme ecocentrists are **deep ecologists**.
- The **anthropocentric** worldview **– believes humans must sustainably manage the global system**. This might be through the use of taxes, environmental regulation and legislation. Is human-centred – in which humans are not dependent on nature but nature is there to benefit humankind.
- The **technocentric** worldview – **believes that technological developments can provide solutions to environmental problems**. **Environmental managers** are technocentrists. Extreme technocentrists are **cornucopians**.

Many in the industrial world have an **anthropocentric** (human-centred) or **technocentric** (planetary management) worldview. In this humans are seen as the dominant species on Earth and we can manage the environment to suit our needs. Other species only then have value if they are useful to us. This can be summarized as:

- We are the Earth's most important species, we are in charge.
- There will always be more resources to exploit.
- We will control and manage these resources and be successful.
- We can solve any pollution problem that we cause.
- Economic growth is a good thing and we can always keep the economy growing.
- In summary – whatever we do, we can solve it.

**Cornucopians** include those people who see the world as having infinite resources to benefit humanity. Cornucopians think that through technology and our inventiveness, we can solve any environmental problem and continually improve our living standards. For them, it is growth that will provide the answers and wealth to improve the lot of all and nothing should stand in the way of this. This paradigm sees a free-market economy – capitalism with minimal government control or interference – as the best way to manage markets and the planet. Some see the Earth as a spaceship and we are its captain and crew. If we understand the machine, we can steer it.

**Environmental managers** see the Earth as a garden that needs tending – the **stewardship** worldview. We have an ethical duty to protect and nurture the Earth. Environmental managers hold the view that there are problems and we need governments to legislate to protect the environment and resources from overexploitation and to make sustainable economies. We may need to compensate those who suffer from environmental degradation and the state has a duty to intervene. Environmental managers believe that if we look after the planet, it looks after us.

The **ecocentric** worldview believes that the views above are too simplistic. We do not even know what species are alive on Earth at the moment and certainly do not know how they interact so it is arrogant of us to think that we can manage it all. To think that we can continue economic growth until every person alive has as high a standard of living as the most affluent is just not possible and so we shall either fall off the treadmill of growth or find it stops beneath us.

**Biocentric** (life-centred) thinkers see all life as having an inherent value – a value for its own sake, not just for humans. So animals are not just for hunting and eating, trees for logging, lakes for fishing. We should not cause the premature extinction of any other species, whether it does us harm or good or neither. An extreme view of this is that we should not cause the harm of any individual of a species, which is what animal rights activists believe. Others who also call themselves ecocentric (earth-centred) broaden this out to the protection of ecosystems and habitats in which the species live. If we can preserve the ecological integrity and complexity of systems, then life will thrive. To broaden this further, some emphasize the holistic nature of our ethical obligation to the Earth. We are just one species, no more important than the others. Because we are sentient beings and can alter our environment, it is our duty to

restore degraded ecosystems, remove pollution and deal with global environmental problems.

To summarize the ecocentric view:

- The Earth is here for all species.
- Resources are limited.
- We should manage growth so that only beneficial forms occur.
- We must work with the Earth, not against it.
- We need the Earth more than it needs us.

Ecocentrists believe in the importance of small-scale, local community action and the actions of individuals making a difference. They view materialism and our need for more as wrong and do not like centralized decision-making.

At the end of the continuum are the **deep ecologists** who put more value on nature than humanity. They believe in biorights – universal rights where all species and ecosystems have an inherent value and humans have no right to interfere with this. Deep ecologists would like policies to be altered to reduce our impact on the environment, which includes a decrease in the human population and consuming less. Deep ecology is not an ecoreligion but a set of guidelines and values to help us think about our relationship with the Earth and our obligations towards it.

Another way of looking at these environmental value systems is to consider them as nurturing (ecocentric) and intervening or manipulative (technocentric/anthropocentric). These are two extremes of the spectrum on environmental values but most of us also think in both ecocentric and technocentric ways about issues and we may change our minds depending on various factors and as we get older. It is too simplistic to say that we fit into one or the other group all the time.

*'A thing is right when it tends to preserve the integrity, stability and beauty of the biotic community. It is wrong when it tends otherwise.'*

Aldo Leopold
(reprinted by permission of Oxford University Press, USA)

As we can only experience the world through our human perceptions, our views of the environment are biased by this viewpoint. We talk of animal rights but can only discuss these using our anthropocentric viewpoint. Most of us will take an accommodating view of the environment ('light-green') – faith in the ability of our institutions to adapt to environmental demands and changes and in communities to work together to reduce resource use (eg bottle banks, recycling aluminium cans) – and so be classified as environmental managers in figure 1.1.6. Some of us are cornucopians ('bright-green') with faith in the appliance of science to solve environmental problems and very few are deep ecologists ('deep-green' or 'dark-green') who believe in green rights and the survival of the Earth above the survival of the human species.

## To think about

### Cost-benefit analysis and the environment

Environmental economists working in industry may be asked how much pollution should be removed from a smokestack of a chimney before the waste is released to the atmosphere. All the pollutant could be removed but at a high cost financially and, in doing so, the company may not be able to afford cleaning up the outflow of heavy metals into a nearby ditch. The opportunity cost of the action is high. There are limited funds and unlimited demands on those funds. Usually costs are passed on to the consumer. So decisions may have to be made that mean some pollution escapes but both demands are met to some extent. Often a cost-benefit analysis is carried out to trade off the costs and benefits.

But valuing the environmental cost is very difficult and it can be argued that cost-benefit analysis cannot apply to these nonmarket effects. How do you value an undisturbed ecosystem or a wild animal or human health? Cost-benefit analysis is still used in decision-making for industry as it is transparent but it may not be the best way. Later in this book, we talk more about how to value the environment, but do be aware that an environmentalist may not always promote the total clean-up or eliminate solution if the opportunity cost is too high. When you add in questions of ethical practice and what is fair to do, you can see how complex this can become.

## Practical Work

* For a named local environmental issue, investigate the relationship between position in society and EVS.
* Investigate the relationship between age and environmental attitudes. Investigate the relationship between gender and environmental attitudes.
* Ecosystems may often cross national boundaries and this may lead to conflict arising from the clash of different value systems about exploitation of resources. For one named example (eg ocean fishing, whaling, tropical rainforest exploitation, Antarctica), research the issue and consider the actions taken by different countries in the exploitation of the resources.

## To do

1. Draw a table with two columns labelled 'Ecocentric' and 'Anthropocentric/ Technocentric'.
2. Put each of the words or phrases below in one of these columns. Don't think for too long about each one. Go with your instinct now you have read about environmental value systems.

| | | |
|---|---|---|
| Aesthetic | Earth-centred | Managerial |
| Animal rights | Ecology | Manipulative |
| Authoritarian | Economy | Nurturing |
| Belief in technology | Feminist | Participatory |
| Capitalism | Global co-existence | Preservation |
| Centralist | Holistic | Reductionist |
| Competitive | Human-centred | Seeking progress |
| Consumerism | Individual | Seeking stability |
| Cooperative | Intervening | Utilitarian |

Then put a tick next to the words that best describe your environmental viewpoint.

Draw a line with ecocentric on the left hand side and technocentric/anthropocentric on the right.

Put a cross which you think gives your position and get all your classmates to mark their own as well.

Review this at the end of the course and see if you have moved along the line – to left or right – or moved relative to your classmates.

## To do

Copy and complete this table to show the main points of the different environmental philosophies.

| Environmental value system | Ecocentric | Anthropocentric | Technocentric |
|---|---|---|---|
| Environmental management strategies | | | |
| Environmental philosophies | | | |
| Labels and characteristics | | | |
| Social movements | | | |
| Politics | | | |

## Various environmental worldviews

### Communism and capitalism in Germany

After the Iron Curtain and Berlin Wall fell in Germany in 1989, western journalists rushed to see East Germany and report upon it. Communism was seen as the antidote to capitalist greed and communists claimed that their system could produce more wealth than capitalism and distribute it more evenly, in the process curing social ills including environmental degradation. But journalists reported on a polluted country in East Germany with the Buna chemical works dumping ten times more mercury into its neighbouring river in a day than a comparable West German plant did in a year. And the smoky two-stroke Trabant cars emitting one hundred times as much carbon monoxide as a western car with a catalytic converter. The message was that capitalism would clean up the industry – but it was not such a non-polluter itself. In some ways the paternalistic communist state had protected the interests of primary producers like farmers and fishermen and so the environment. There was a law that made smelters shut down and so not pollute in spring when crops were growing.

*'The earth shall rise on new foundations: We have been nought, we shall be all!'*

Taken from the Internationale, the anthem of international socialists and communists

### Native American environmental worldview

While there are many native American views, a broad generalization of their views is that they tend to hold property in common (communal), have a subsistence economy, barter for goods rather than use money, and use low-impact technologies. Politically, they come to consensus agreements by participation in a democratic process. The laws are handed down by oral tradition. Most communities have a matrilineal line (descent follows the female side) as opposed to patriarchal, with extended families and low population density. In terms of religion, they are polytheistic (worshipping many gods) and hold that animals and plants as well as natural objects have a spirituality.

### Worldviews of Christianity and Islam

The two religions on Earth with the most adherents are Christianity and Islam, together numbering some 3.6 billion. They share the belief in a separation of spirit and matter or body and soul and a notion of 'dominion' or mastery over the Earth. But the ancient Greek view of citizenship and democracy, the Judaic notion of the covenant and the Christian view of unconditional love are examples which have perhaps been distorted in the anthropocentric views of the West. In the biblical book of Genesis, God commands humans to 'replenish the earth, and subdue it; and have dominion over it' (Genesis 1:28). But what does this mean? Are humans to be masters or stewards of the Earth? Do stewards own something or just look after it?

The Quran states that the Earth (and its bounty) has been given to humans for their sustenance. The Quran does differentiate from the Judeo-Christian model in a number of areas however.

**To do**

**Shades of green: Where are we now?**

In any political movement, there will be changes and developments. It is now difficult to avoid marketing that is based on environmental well-being, often related to human well-being. Organic, biotic, low emissions, energy-saving, sustainable, free-range, green credentials are all terms used in green marketing of products although exactly what they mean and how we perceive them is questionable. 'Greenwash' and 'Green sheen' are terms that describe activities that are not as good for the environment as the producer would like us to believe.

A way of classifying environmentalists today is as dark greens, light greens and bright greens.

Dark greens are dissenters seeking political change in a radical way as they believe that economic development and industrial growth are not the answer. They see a change in the status quo and a reduction in the size of the human population as the way to go. Light greens are individuals who do not want to work politically for change but change their own lifestyles to use fewer resources. For them, it is an individual choice. Bright greens want to use technological developments and social manipulation to make us live sustainably and believe that this can be done by innovation. For bright greens, economic growth may be beneficial if it means more of us live in efficient cities, use more renewable energy and reduce the size of our ecological footprints while increasing our standard of living. For them, we can have it all. The viridian design movement is a spin-off from the bright greens and is about global citizenship and improved design of green products.

What shade of green are you?

- Humans are not given mastery or dominion over the Earth but rather have been granted it as a gift or inheritance. This is a significant difference as it implies caretaker status of God's work not rulers over it.
- The Quran also recognises that the animal world is a community equal to the human one.
- There is more emphasis on the trustee status of human beings and thus the imperative towards charity (the 3rd pillar of Islam).[1]

Another layer comes from ecofeminism as an environmental movement in which ecofeminists argue that it is the rise of male-dominated societies since the advent of agriculture that has led to our view of nature as a foe to be conquered rather than a nurturing Earth mother.

## Buddhism's environmental worldview – a religious ecology

Buddhism has evolved over 2,500 years to see the world as conjoined in four ways – morally, existentially, cosmologically and ontologically. Buddhists believe that all sentient beings share the conditions of birth, old age, suffering and death and that every living thing in the world is co-dependent. Buddhist belief teaches that as we are all dependent on each other, whether plant or animal, we are not autonomous and humans cannot be more important than other living things and must extend loving-kindness and compassion not just to life but to the Earth itself.

[1] Personal communication from Kosta Lekanides to the authors.

# 1.2 Systems and models

## Significant ideas:

- A systems approach can help in the study of complex environmental issues.
- The use of models of systems simplifies interactions but may provide a more holistic view than reducing issues to single processes.

## Applications and skills:

- **Construct** a system diagram or a model from a given set of information.
- **Evaluate** the use of models as a tool in a given situation, eg for climate change predictions.

## Knowledge and understanding:

- A **systems approach** is a way of visualizing a complex set of interactions which may be ecological or societal.
- These interactions produce the emergent properties of the system.
- The concept of a system can be applied to a range of scales.
- A system is comprised of **storages and flows**.
- The flows provide inputs and outputs of energy and matter.
- The flows are processes and may be either **transfers** (a change in location) or **transformations** (a change in the chemical nature, a change in state or a change in energy).
- In **system diagrams**, storages are usually represented as rectangular boxes, and flows as arrows with the arrow indicating the direction of the flow. The size of the box and the arrow may represent the size/magnitude of the storage or flow.
- An **open system** exchanges both energy and matter across its boundary while a **closed system** only exchanges energy across its boundary.
- An **isolated system** is a hypothetical concept in which neither energy nor matter is exchanged across the boundary.
- **Ecosystems are open systems**. Closed systems only exist experimentally although the global geochemical cycles approximate to closed systems.
- A **model** is a simplified version of reality and can be used to understand how a system works and predict how it will respond to change.
- A model inevitably involves some approximation and loss of accuracy.

## Why systems?

A system can be living or non-living.

- Systems can be on any scale – small or large. A cell is a system as are you, a bicycle, a car, your home, a pond, an ocean, a smart phone and a farm.
- Open, closed and isolated systems exist in theory though most living systems are open systems.

*'Nature does nothing uselessly.'*

Aristotle (384–322 BC)

- Material and energy undergo transfers and transformations in flowing from one storage to the next.
- Models have their limitations but can be useful in helping us to understand systems.

This course is called Environmental Systems and Societies and not Environmental Science or Studies. Have you considered why this is? There is a difference in emphasis. In the systems approach, the environment is seen as a set of complex systems: sets of components that function together and form integrated units. You study plants, animals, soils, rocks or the atmosphere not separately (as is sometimes the case in other sciences such as biology, geology or geography), but together as the component parts of complex environments. You also study them in relation to other elements of the system of which they are a part. The course takes an integrated view, and this emphasis on relationships and linkages distinguishes the systems approach. We consider ecosystems in this book and they can be on many scales from a drop of pond water to an ocean, a tree to a forest, a coral reef to an island continent. A biome can be seen as an ecosystem, though it helps if an ecosystem has clear boundaries. The whole biosphere is an ecosystem as well.

**Key term**

A **system** is a set of inter-related parts working together to make a complex whole.

We also consider other systems such as the social and economic systems that make our human world work. Decisions about the environment are rarely simply decisions based on ecology or science. We may want to save the tigers but will be constrained by economics, society and political systems which all influence decisions we make.

A system may be an abstract concept as well as something tangible. It is a way of looking at the world. Usually, we can draw a system as a diagram. The environmental value system that you hold consists of your opinions on the environment and how you evaluate it.

A system may remain stable for a long time or may change quickly. Systems occur within their own environment which may be made up of other systems or ecosystems, and they usually exchange inputs and outputs – energy and matter in living systems, information in non-living ones – with their environment. Systems are all more than the sum of their parts, for example a computer is more than the materials used to make it.

▲ **Figure 1.2.1** The Earth and its Moon viewed from space

## The human place in the biosphere

The biosphere is a fragile skin on the planet Earth. It includes the air (atmosphere), rocks (lithosphere) and water (hydrosphere) within which life occurs. Humans and all other organisms live within this thin layer yet we know little about how it is regulated or self-regulates, or about the effects the human species is having upon it.

## Types of system

Systems can be thought of as one of three types: open, closed and isolated.

An **open system** exchanges matter and energy with its surroundings (see figure 1.2.3).

biosphere = atmosphere + lithosphere + hydrosphere + ecosphere

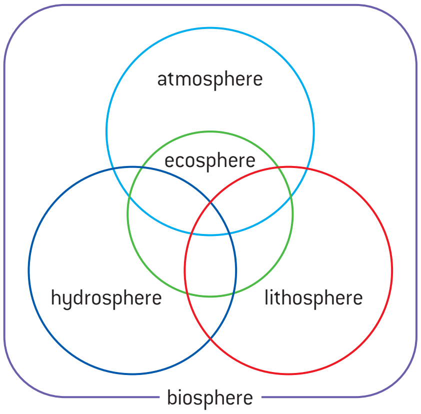



**Figure 1.2.2** Relationships within the biosphere

| All systems have: | Represented by: |
|---|---|
| STORAGES or stores of matter or energy | a box |
| FLOWS into, through and out of the system | arrows |
| INPUTS | arrows in |
| OUTPUTS | arrows out |
| BOUNDARIES | lines |
| PROCESSES which transfer or transform energy or matter from storage to storage | Eg respiration, precipitation, diffusion |

**Figure 1.2.3** Systems terminology

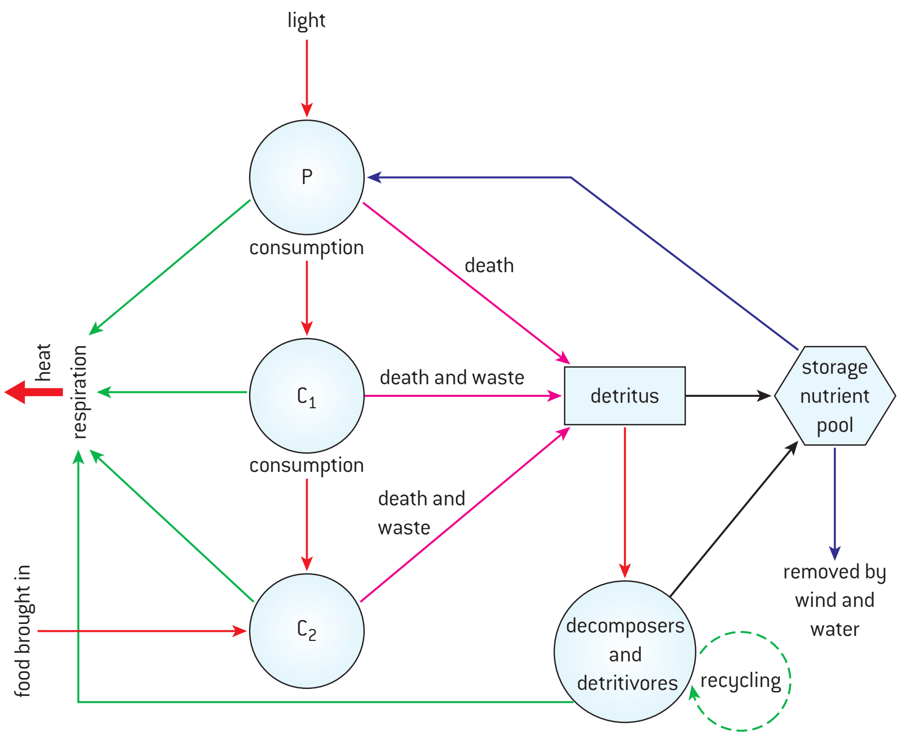



**Figure 1.2.4** Energy and matter exchange in an immature forest ecosystem

## Transfers and transformations

Both matter (or material) and energy move or flow through ecosystems as:

- transfers: water moving from a river to the sea, chemical energy in the form of sugars moving from a herbivore to a carnivore or:
  - the movement of material through living organisms (carnivores eating other animals)
  - the movement of material in a non-living process (water being carried by a stream)
  - the movement of energy (ocean currents transferring heat).

## Key terms

**Transfers** occur when energy or matter flows and changes location but does not change its state.

**Transformations** occur when energy or matter flows and changes its state – a change in the chemical nature, a change in state or a change in energy.

## Practical Work

* Create a model ecosystem in a plastic soda bottle (sub-topic 5.4).
* Construct a model of your home, with storages and flows.
* Evaluate climate change models (7.2).

- transformations: liquid to gas, light to chemical energy:
  - matter to matter (soluble glucose converted to insoluble starch in plants)
  - energy to energy (light converted to heat by radiating surfaces)
  - matter to energy (burning fossil fuels)
  - energy to matter (photosynthesis).

Both types of flow require energy; transfers, being simpler, require less energy and are therefore more efficient than transformations.

## Flows and storages

Both energy and matter flow (as inputs and outputs) through ecosystems but, at times, they are also stored (as storages or stock) within the ecosystem.

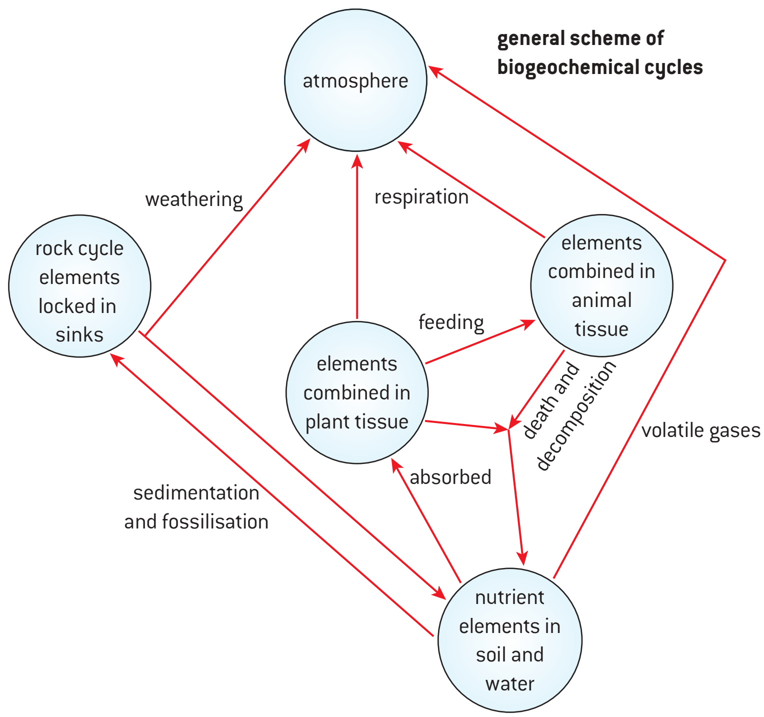



**Figure 1.2.5** The Biogeochemical Cycle illustrating the general flows in an ecosystem. Energy flows from one compartment to another, eg in a food chain. But when one organism eats another organism, the energy that moves between them is in the form of stored chemical energy: the body of the prey organism

## More on systems

## To do

**Examples of systems**

An ecosystem is a good example of a 'system'.

Using the model below, draw your own systems diagram for:

a) A candle
b) A mobile phone
c) A green plant
d) You
e) Your school
f) A lake

**Label the inputs, outputs, storages and flows.**

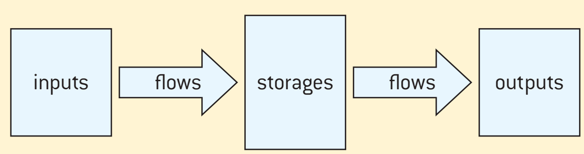



**Figure 1.2.6**

Most systems are **open systems**. All ecosystems are open systems exchanging matter and energy with their environment.

In forest ecosystems:

- Plants fix energy from light entering the system during photosynthesis.
- Nitrogen from the air is fixed by soil bacteria.
- Herbivores that live within the forest may graze in adjacent ecosystems such as a grassland, but when they return they enrich the soil with feces.
- Forest fires expose the topsoil which may be removed by wind and rain.
- Mineral nutrients are leached out of the soil and transported in groundwater to streams and rivers.
- Water is lost through evaporation and transpiration from plants.
- Heat is exchanged with the surrounding environment across the boundaries of the forest.

Open system models can even be applied to the remotest oceanic island – energy and matter are exchanged with the atmosphere, surrounding oceans and even migratory birds.

A **closed system** exchanges energy but not matter with its environment.

Closed systems are extremely rare in nature. However, on a global scale, the hydrological, carbon, and nitrogen cycles are closed – they exchange only energy and no matter. The planet itself can be thought of as an 'almost' closed system.

Light energy in large amounts enters the Earth's system and some is eventually returned to space as long-wave radiation (heat). (Because a small amount of matter is exchanged between the Earth and space, it is not truly a closed system. What types of matter can you think of that enter the Earth's atmosphere and what types that leave it?)

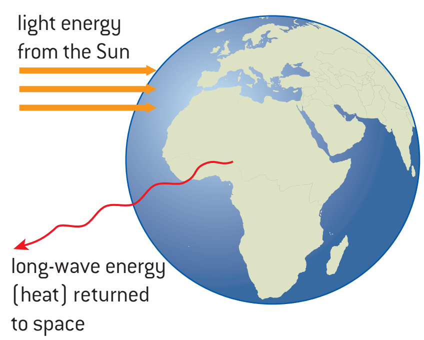



**Figure 1.2.7** A closed system – the Earth

Most examples of closed systems are artificial, and are constructed for experimental purposes. An aquarium or terrarium may be sealed so that only energy in the form of light and heat but not matter can be exchanged. Examples include bottle gardens or sealed terraria but they usually do not survive for long as the system becomes unbalanced, for example not enough food for the animals, or not enough oxygen or carbon dioxide, and organisms die. An example of a closed system that went wrong is Biosphere 2 (see p 22). An example of a closed system that is in equilibrium is at http://www.dailymail.co.uk/sciencetech/article-2267504/The-sealed-bottle-garden-thriving-40-years-fresh-air-water.html

An **isolated system** exchanges neither matter nor energy with its environment. Isolated systems do not exist naturally though it is possible to think of the entire universe as an isolated system.

| System | Energy exchanged | Matter exchanged |
|---|---|---|
| Open | Yes | Yes |
| Closed | Yes | No |
| Isolated | No | No |

## To think about

### Biosphere 2

Biosphere 2, a prototype space city, was a human attempt to create a habitable closed system on Earth. Built in Arizona at the end of the 1980s, Biosphere 2 was a three-hectare greenhouse intended to explore the use of closed biospheres in space colonization. Two major 'missions' were conducted but both ran into problems. The Biosphere never managed to produce enough food to adequately sustain the participants and at times oxygen levels became dangerously low and needed augmenting – they opened the windows so making it an open system.

▲ **Figure 1.2.8** Biosphere 2

Inside were various ecosystems: a rainforest, coral reef, mangroves, savanna, desert, an agricultural area and living quarters. Electricity was generated from natural gas and the whole building was sealed off from the outside world.

For two years, eight people lived in Biosphere 2 in a first trial. But oxygen levels dropped from 21% to 14% and of the 25 small animal species put in, 19 became extinct, while ants, cockroaches and katydids thrived. Bananas grew well but there was not enough food to keep the eight people from being hungry. Oxygen levels gradually fell and it is thought that soil microbes respired much of this. Carbon dioxide levels fluctuated widely. A second trial started in 1994 but closed after a month when two of the team vandalized the project, opening up doors to the outside. Cooling the massive greenhouses was an issue, using three units of energy from air conditioners to cool the air for the input of every one unit of solar energy. So there were social, biological and technological problems with the project as the team split into factions and questions were asked as to whether this was a scientific, business or artistic venture.

The result was to show how difficult it is to make a sustainable closed system when the complexities of the component ecosystems are not fully understood.

## To do

There is a TED talk about this http://www.ted.com/talks/jane_poynter_life_in_biosphere_2. Watch it.

**Questions**

1. Why do you think this was called Biosphere 2?
2. Biosphere 2 has been described as a 'closed system'. What does this mean?
3. Biosphere 2 was designed to include some of the major ecosystems of the Earth.
4. List the ecosystems and divide them into terrestrial (land based) and marine (sea-water based).

## To think about

**Atoms**

All matter is made up of atoms. You are taught this in some of your first science lessons. Living things are made up of atoms, grouped into molecules and macromolecules, organelles, cells, tissues, organs and systems.

Read these two excerpts and think about what makes you you.

**From 'Quantum theory and relativity explained' (Daily Telegraph 20th November 2007)**

'Quantum theory has made the modern world possible, giving us lasers and computers and iPod nanos, not to mention explaining how the sun shines and why the ground is solid.

Take the fact that you are constantly inhaling fragments of Marilyn Monroe. It is stretching it a bit to say that this is a direct consequence of quantum theory.

Nevertheless, it is connected to the properties of atoms, the Lego bricks from which we are all assembled, and quantum theory is essentially a description of this microscopic world.

The important thing to realize is that atoms are small. It would take about 10 million of them laid end to end to span the full stop at the end of this sentence. It means that every time you breathe out, uncountable trillions of the little blighters spread out into the air.

Eventually the wind will spread them evenly throughout the Earth's atmosphere. When this happens, every lungful of the atmosphere will contain one or two atoms you breathed out.

So, each time someone inhales, they will breathe in an atom breathed out by you – or Marilyn Monroe, or Alexander the Great, or the last *Tyrannosaurus rex* that stalked the Earth.'

**From Bill Bryson's 'A Short History of Nearly Everything'**

'Why atoms take this trouble is a bit of a puzzle. Being you is not a gratifying experience at the atomic level. For all their devoted attention, your atoms do not actually care about you—indeed, they do not even know that you are there. They don't even know that they are there. They are mindless particles, after all, and not even themselves alive. (It is a slightly arresting notion that if you were to pick yourself apart with tweezers, one atom at a time, you would produce a mound of fine atomic dust, none of which had ever been alive but all of which had once been you.) Yet somehow for the period of your existence they will answer to a single overarching impulse: to keep you you.

The bad news is that atoms are fickle, and their time of devotion is fleeting indeed. Even a long human life adds up to only about 650,000 hours, and when that modest milestone flashes past, for reasons unknown, your atoms will shut you down, silently disassemble, and go off to be other things. And that's it for you. Still, you may rejoice that it happens at all. Generally speaking in the universe, it doesn't...so far as we can tell.'

Bill Bryson continues to say that 'life is simple in terms of chemicals – oxygen, hydrogen, carbon, nitrogen make up most of all living things and a few other elements too – sulfur, calcium and some others. But in combination and for a short time, they can make you and that is the miracle of life.'

## Models of systems

A model is a simplified version of the real thing. We use models to help us understand how a system works and to predict what happens if something changes. Systems work in predictable ways, following rules, we just do not always know what these rules are. A model can take many forms. It could be:

- a physical model, for example a wind tunnel or river, a globe or model of the solar system, an aquarium or terrarium
- a software model, for example of climate change or evolution (Lovelock's Daisyworld)

- mathematical equations
- data flow diagrams.

Models have their limitations as well as strengths. While they may omit some of the complexities of the real system (through lack of knowledge or for simplicity), they allow us to look ahead and predict the effects of a change to an input to the system.

## To do

**Compare these two models**

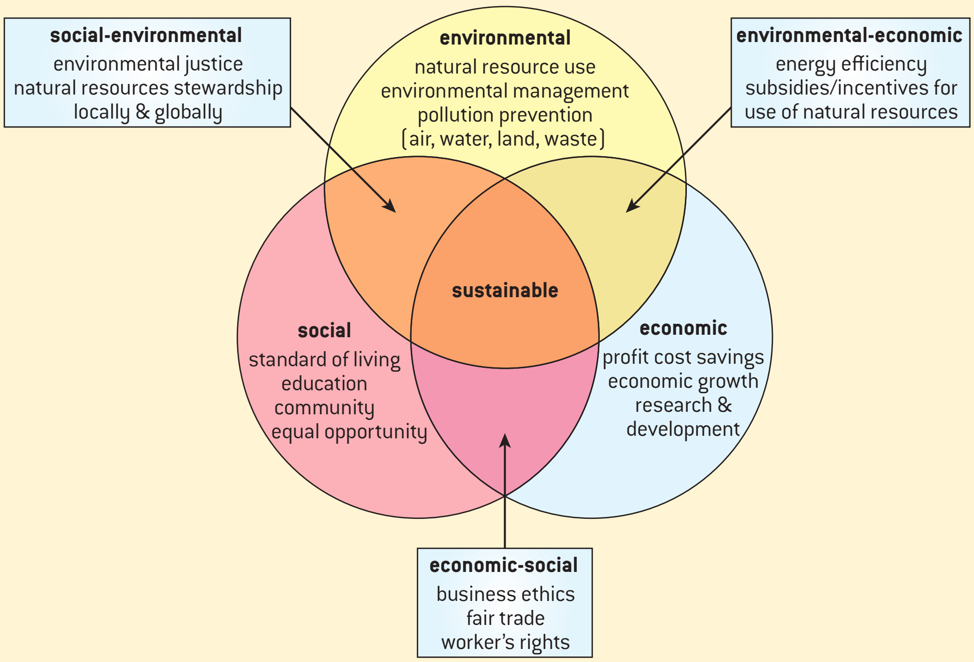



**Figure 1.2.9** The spheres of a sustainable model. Only when all three overlap is there sustainability

Why are any of these circles in the Venn diagram outside the environment?

Is culture relevant to these models of sustainability? Where would you draw it in?

Does the model change how we treat our environment?

Evaluate these models. (Consider their strengths and weaknesses.)

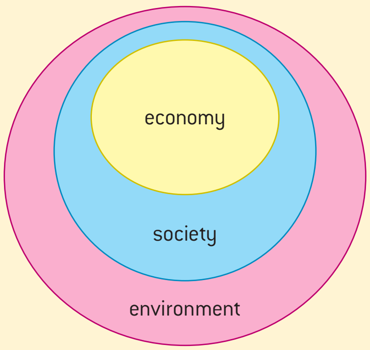



**Figure 1.2.10** An alternative model of sustainability representing all other systems within the environmental system

The strengths of models are:

- Easier to work with than complex reality.
- Can be used to predict the effect of a change of input.
- Can be applied to other similar situations.
- Help us see patterns.
- Can be used to visualize really small things (atoms) and really large things (solar system).

The weaknesses of models are:

- Accuracy is lost because the model is simplified.
- If our assumptions are wrong, the model will be wrong.
- Predictions may be inaccurate.

## Sustainable development modelling

See 1.4 for more on sustainable development and sustainability.

### To do

http://gingerbooth.com/flash/daisyball/ links to the Daisyworld game. Have a go.

### To think about

**Gaia – a model of the Earth**

The 'Great Aerial Ocean' was Alfred Russel Wallace's description of the atmosphere.

'You can cut the atmosphere with a knife' is a common saying. If we could see the atmosphere, perhaps we would consider it and look after it more. As we cannot, perhaps we take it for granted.

In 1979, James Lovelock published *The Gaia Hypothesis*. In it he argued that the Earth is a planet-sized organism and the atmosphere is its organ that regulates it and connects all its parts. (Gaia is an Ancient Greek Earth goddess.) Lovelock argued that the biosphere keeps the composition of the atmosphere within certain boundaries by negative feedback mechanisms.

He based his argument on these facts:

1. The temperature at the Earth's surface is constant even though the Sun is giving out 30% more energy than when the Earth was formed.
2. The composition of the atmosphere is constant with 79% nitrogen, 21% oxygen and 0.03% carbon dioxide. Oxygen is a reactive gas and should be reacting but it does not.
3. The oceans' salinity is constant at about 3.4% but rivers washing salts into the seas should increase this.

He was much criticized over this hypothesis but Lynn Margulis who worked with him also supported his views though uses less emotive language about the Earth as an organism. Lovelock has defended his hypothesis for 30 years and many people are now accepting some of his views. He developed a Daisyworld as a mathematical simulation to show that feedback mechanisms can evolve from the activities of self-interested organisms – black and white daisies in this case.

In Lovelock's 2007 book, *The Revenge of Gaia*, he makes a strong case for the Earth being an 'older lady' now, more than half way through her existence as a planet and so not being able to bounce back from changes as well as she used to. He suggests that we may be entering a phase of positive feedback when the previously stable equilibrium will become unstable and we will shift to a new, hotter equilibrium state. Controversially, he suggests that the human population will survive but with a 90% reduction in numbers.

## To do

1. Define a system
2. Fill in the gaps

The terms 'open', 'closed' and 'isolated' are used to describe particular kinds of systems. Match the above names to the following definitions:

- *A_____ system exchanges matter and energy with its surroundings (eg an ecosystem).*
- *A_____ system exchanges energy but not matter* (The 'Biosphere 2' experiment was an attempt to model this. These systems do not occur naturally on Earth, although the biosphere (or Gaia) itself can be considered a ____ system.)
- *A_____ system exchanges neither matter nor energy.* (No such systems exist, with the possible exception of the entire cosmos.)

All ecosystems are ____ systems, because of the input of ___ energy and the exchange of ____ with other ecosystems.

3. Systems circus

*Look at the following simple systems and complete the table:*

| | **Burning candle** | **Boiling kettle** | **A plant** | **Animal population** |
|---|---|---|---|---|
| Inputs | | | | |
| Outputs | | | | |
| Energy and material transfers | | | | |
| Energy and material transformations | | | | |

# 1.3 Energy and equilibria

## Significant ideas:

- The laws of thermodynamics govern the flow of energy in a system and the ability to do work.
- Systems can exist in alternative stable states or as equilibria between which there are tipping points.
- Destabilizing positive feedback mechanisms will drive systems toward these tipping points, whereas stabilizing negative feedback mechanisms will resist such changes.

## Applications and skills:

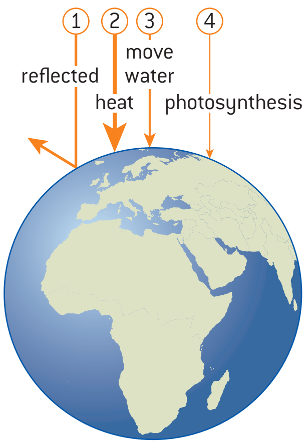
- **Explain** the implications of the laws of thermodynamics to ecological systems.
- **Discuss** resilience in a variety of systems.
- **Evaluate** the possible consequences of tipping points.

## Knowledge and understanding:

- The **first law of thermodynamics** is the **principle of conservation of energy**, which states that energy in an isolated system can be transformed but cannot be created or destroyed.
- The principle of conservation of energy can be modelled by the energy transformations along food chains and energy production systems.
- The **second law of thermodynamics** states that the entropy of a system increases over time. **Entropy** is a measure of the amount of disorder in a system. An increase in entropy arising from energy **transformations** reduces the energy available to do work.
- The second law of thermodynamics explains the inefficiency and decrease in available energy along a food chain and energy generation systems.
- As an open system, an ecosystem, will normally exist in a **stable equilibrium**, either a **steady-state** or one developing over time (eg succession), and maintained by stabilizing negative feedback loops.
- **Negative feedback loops** (stabilizing) occur when the output of a process inhibits or reverses the operation of the same process in such a way to reduce change – it counteracts deviation.
- **Positive feedback loops** (destabilizing) will tend to amplify changes and drive the system toward a tipping point where a new equilibrium is adopted.
- The **resilience** of a system, ecological or social, refers to its tendency to avoid such tipping points and maintain stability.
- Diversity and the size of storages within systems can contribute to their resilience and affect the speed of response to change (time lags).
- Humans can affect the resilience of systems through reducing these storages and diversity.
- The delays involved in feedback loops make it difficult to predict **tipping points** and add to the complexity of modelling systems.

## Key terms

The **first law of thermodynamics** is the **principle of conservation of energy**, which states that energy in an isolated system can be transformed but cannot be created or destroyed.




▲ **Figure 1.3.2** The fate of the Sun's energy hitting the Earth. About 30% is reflected back into space (1), around 50% is converted to heat (2), and most of the rest powers the hydrological cycle: rain, evaporation, wind, etc (3). Less than 1% of incoming light is used for photosynthesis (4).

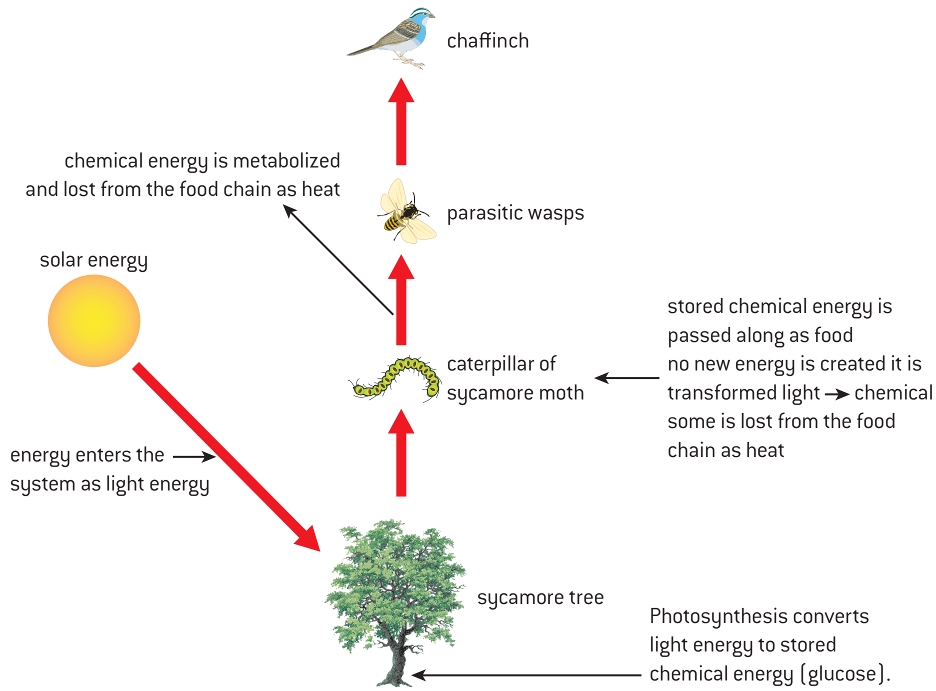
## Key terms

The **second law of thermodynamics** refers to the fact that energy is transformed through energy transfers. **Entropy** is a measure of the amount of disorder in a system. An increase in entropy arising from energy **transformations** reduces the energy available to do work.

# Energy in systems

Energy in all systems is subject to the laws of thermodynamics.

According to the **first law of thermodynamics**, energy is neither created nor destroyed. What this really means is that the total energy in any isolated system, such as the entire universe, is constant. All that can happen is that the form the energy takes changes. This first law is often called the **principle of conservation of energy.**




▲ **Figure 1.3.1** A simple food chain

In a power station, one form of energy (from eg coal, oil, nuclear power, moving water) is converted or transformed into electricity.

In your body, food provides chemical energy which you convert into heat or kinetic energy.

If we look at the sunlight falling on Earth, not all of it is used for photosynthesis.

The **second law of thermodynamics** states that the **entropy** of an isolated system not in equilibrium will tend to increase over time.

- Entropy is a measure of disorder of a system and it refers to the spreading out or dispersal of energy.
- More entropy = less order.
- Over time, all differences in energy in the universe will be evened out until nothing can change.
- Energy conversions are never 100% efficient.
- When energy is used to do work, some energy is always dissipated (lost to the environment) as waste heat.

This process can be summarized by a simple diagram showing the energy input and outputs.

energy = work + heat (and other wasted energy)

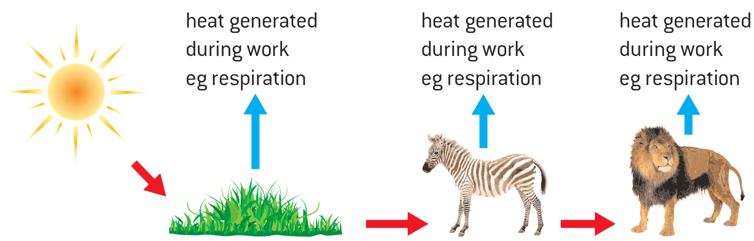



**Figure 1.3.4** Loss of energy to the environment in a food chain

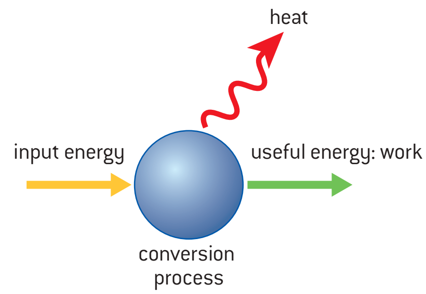



**Figure 1.3.3** The second law of thermodynamics

In the example in figure 1.3.4, the energy spreads out so the useful energy consumed by one trophic level is less than the total energy at the level below.

- Depending on the type of plant, the efficiency at converting solar energy to stored sugars is around 1–2%.
- Herbivores on average only assimilate (turn into animal matter) about 10% of the total plant energy they consume. The rest is lost in metabolic processes and escaping from the carnivore. This changes the stored chemical energy in its cells into useful work (running). But during its attempted escape some of the stored energy is converted to heat and lost from the food chain.
- A carnivore's efficiency is also only around 10% (see 2.3). As with the herbivore they metabolize stored chemical energy, in this case trying to catch the herbivore.
- So as energy is dispersed to the environment, there will always be a reduction in the amount of energy passed on to the next trophic level.
- That means the carnivore's total efficiency in the chain is 0.02 × 0.1 × 0.1 = 0.0002%.
- This means the carnivore loses most of its energy as heat into the surrounding environment.

## Key term

**Entropy** is a measure of the amount of disorder in a system.

Life is a battle against entropy and, without the constant replenishment of energy, life cannot exist. Consider this pictorial view (figure 1.3.5) of paddling upstream. Stop for a moment and you are swept back downstream by the current of entropy.

Simple example of entropy:

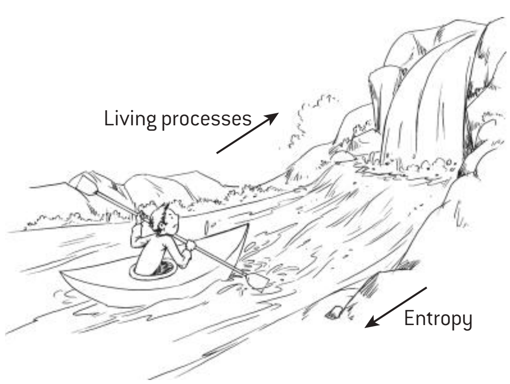
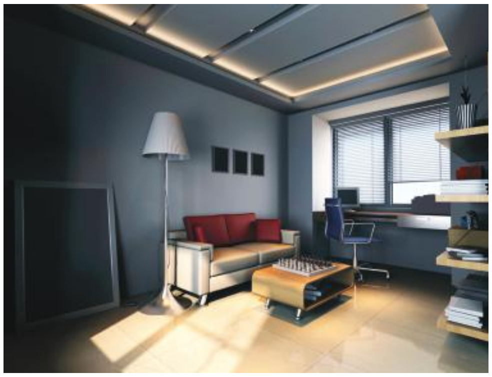



**Figure 1.3.5** A representation of life against entropy



Tidy room has order: low entropy
Does this happen naturally without the input of energy?

Untidy room has disorder: high entropy

▲ **Figure 1.3.6** Which is your room?

The situation depicted in figure 1.3.6 obeys the second law of thermodynamics, since the tidy room of low entropy becomes untidy, a situation of high entropy. In the process, entropy increases spontaneously.

Solar energy powers photosynthesis. Chemical energy, through respiration, powers all activities of life. Electrical energy runs all home appliances. The potential energy of a waterfall turns a turbine to produce electricity. These are all high-quality forms of energy, because they power useful processes. They are all ordered forms of energy. Solar energy reaches us via photons in solar rays; chemical energy is stored in the bonds of macromolecules like sugars; the potential energy of falling water is due to the specific position of water, namely that it is high and falls. These ordered forms have low disorder, so low entropy.

On the contrary, heat may not power any process; it is a low-quality form of energy. Heat is simply dispersed in space, being capable only of warming it up. Heat dissipates to the environment without any order; it is disordered. In other words, heat is a form of energy characterized by high entropy.

## To think about

**Implications of the second law for environmental systems**

We experience the second law in our everyday lives. All living creatures die and in doing so:

- entropy or disorder tends to increase
- the creatures move from order to disorder
- but organisms manage to 'survive' against the odds, that is against the second law of thermodynamics
- living creatures manage to maintain their order and defy entropy to stay alive by continuous input of energy by continuously getting chemical energy from organic compounds via respiration
- energy is even required at rest – if they do not respire they die.

This is the same as the example of the room; the only way to keep the room tidy is to continuously clean it, that is to expend energy.

In any process, some of the useful energy turns into heat:

- Low-entropy (high-quality) energy degrades into high-entropy (low-quality) heat.
- So the entropy of the living system stays low, whilst the entropy of the environment is increasing.
- Photosynthesis and respiration are good examples.
  - Low-entropy solar energy turns into higher-entropy chemical energy.
  - Chemical energy turns into even higher-entropy mechanical energy and is 'lost' as heat (low-quality, high-entropy).
- This increases the entropy of the environment, in which heat dissipates.
- As a consequence, no process can be 100% efficient.

**TOK**

A last philosophical implication is that, according to physics, the fate of all the energy that exists today in the universe is to degrade into high-entropy heat. When all energy has turned into heat, the whole universe will have a balanced temperature, and no process will be possible any longer, since heat may not turn into something of higher entropy. This is referred to as the thermal death of the universe.

What may happen after that?

**Key term**

**Efficiency** is defined as the useful energy, the work or output produced by a process divided by the amount of energy consumed being the input to the process:

efficiency = work or energy produced / energy consumed

efficiency = useful output/ input

Multiply by 100%, if you want to express efficiency as a percentage.

## Complexity and stability

Most ecosystems are very complex. There are many feedback links, flows and storages. It is likely that a high level of complexity makes for a more stable system which can withstand stress and change better than a simple one can, as another pathway can take over if one is removed. Imagine a road system where one road is blocked by a broken-down truck; vehicles can find an alternative route on other roads. If a community has a number of predators and one is wiped out by disease, the others will increase as there is more prey for them to eat and prey numbers will not increase. If on the other hand systems are simple they may lack stability.

- Tundra ecosystems are fairly simple and thus populations in them may fluctuate widely, eg lemming population numbers.
- Monocultures (farming systems in which there is only one major crop) are also simple and thus vulnerable to the sudden spread of a pest or disease through a large area with devastating effect. The spread of potato blight through Ireland in 1845–8 provides an example; potato was the major crop grown over large areas of the island, and the biological, economic and political consequences were severe.

**Key term**

**Negative feedback loops** are stabilizing and occur when the output of a process inhibits or reverses the operation of the same process in such a way to reduce change – it counteracts deviation.

## Equilibrium

Equilibrium is the tendency of the system to return to an original state following disturbance; at equilibrium, a state of balance exists among the components of that system.

We can think of systems as being in dynamic (steady-state) or static equilibria as well as in stable or unstable equilibria. We discuss each of these here. Note that the term steady-state equilibrium is used instead of dynamic equilibrium in this book.

Open systems tend to exist in a state of balance or stable equilibrium. Equilibrium avoids sudden changes in a system, though this does not mean that all systems are non-changing. If change exists it tends to exist between limits.

A **steady-state equilibrium** is a characteristic of open systems where there are continuous inputs and outputs of energy and matter, but the system as a whole remains in a more-or-less constant state (eg a climax ecosystem).

**Key term**

A **steady-state equilibrium** is a characteristic of open systems where there are continuous inputs and outputs of energy and matter, but the system as a whole remains in a more-or-less constant state (eg a climax ecosystem).

**Negative feedback** stabilizes steady-state equilibria. It tends to damp down, neutralize or counteract any deviation from an equilibrium, and it stabilizes systems or results in steady-state (dynamic) equilibrium. It results in self-regulation of a system.

In a steady-state equilibrium there are no long-term changes but there may be small fluctuations in the short term, eg in response to weather changes, and the system will return to its previous equilibrium condition following the removal of the disturbance.

Some systems may undergo long-term changes to their equilibrium as they develop over time while retaining integrity to the system. Successions (see 2.4) are good examples of this.

## Examples of a steady-state equilibrium

1. A water tank. If it fills at the same rate that it empties, there is no net change but the water flows in and out. It is in a steady state.
2. In economics, a market may be stable but there are flows of capital in and out of the market.
3. In ecology, a population of ants or any organism may stay the same size but individual organisms are born and die. If these birth and death rates are equal, there is no net change in population size.
4. A mature, climax ecosystem, like a forest, is in steady-state equilibrium as there are no long-term changes. It usually looks much the same for long periods of time, although all the trees and other organisms are growing, dying and being replaced by younger ones. However, there are flows in and out of the system – light inputs from the sun, energy outputs as heat lost through respiration; matter inputs in rainwater and gases, outputs in salts lost in leaching and rain washing away the soil. However, over years, the inputs and outputs balance.
5. Another example of a steady-state equilibrium is people maintaining a constant body weight, thus 'burning' all the calories (energy) we get from our food. In cases of increasing or decreasing body weight there is no steady state.
6. The maintenance of a constant body temperature is another example. We sweat to cool ourselves and shiver to warm up but our body core temperature is about 37 °C.

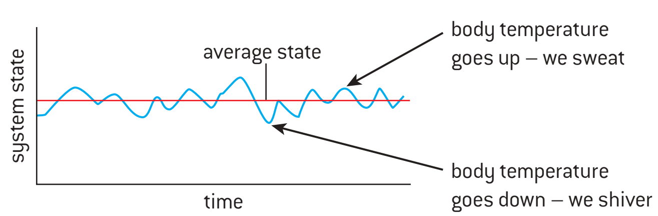



**Figure 1.3.7** Steady-state equilibrium

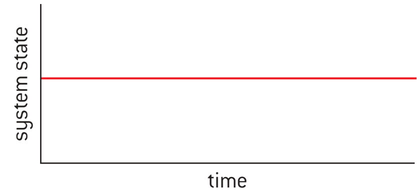
Maintenance of a steady-state equilibrium is achieved through negative feedback mechanisms, as we shall see later.

## Static equilibrium

Another kind of equilibrium is called a **static equilibrium**, in which there is no change over time, eg a pile of books which does not move unless toppled over. When a static equilibrium is disturbed it will adopt a new equilibrium as a result of the disturbance. A pile of scree material (a mass of weathered rock fragments) piled up against a cliff could be said to exist in static equilibrium. The forces within the system are in balance, and the components (the rock fragments, the cliff and the valley floor) remain unchanged in their relationship to one another for long periods of time.

Most non-living systems like a pile of rocks or a building are in a state of static equilibrium. This means that they do not change their position or state, ie they look the same for long periods of time and the rocks or bricks stay in the same place.

This cannot occur in living systems as life involves exchange of energy and matter with the environment.




▲ **Figure 1.3.8** Static equilibrium

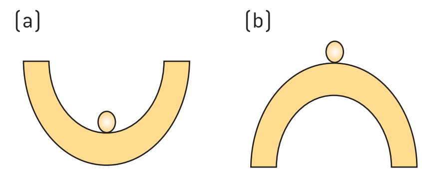
## Unstable and stable equilibria

Systems can also be **stable** or **unstable**.

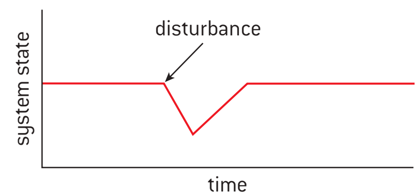
In a stable equilibrium the system tends to return to the same equilibrium after a disturbance.

In an unstable equilibrium the system returns to a new equilibrium after disturbance.

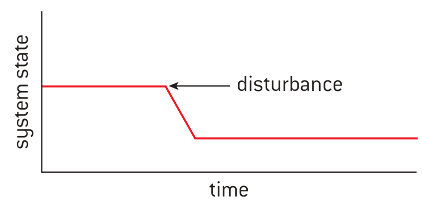
Possibly this is happening to our climate and the new state will be hotter.




▲ **Figure 1.3.9** Diagrams of (a) stable and (b) unstable equilibrium




▲ **Figure 1.3.10** Stable equilibrium




▲ **Figure 1.3.11** Unstable equilibrium

# Feedback loops

Systems are continually affected by information from outside and inside the system. Simple examples of this are:

1. If you start to feel cold you can either put on more clothes or turn the heating up. The sense of cold is the information, putting on clothes is the reaction.
2. If you feel hungry, you have a choice of reactions as a result of processing this 'information': eat food, or do not eat and feel more hungry.

Natural systems act in exactly the same way.

Feedback loop mechanisms can either be:

- Positive:
  - Change a system to a new state.
  - Destabilizing as they increase change.
- Negative
  - Return it to its original state.
  - Stabilizing as they reduce change.

**Key term**

A **feedback loop** is when information that starts a reaction in turn may input more information which may start another reaction.

## Examples of negative feedback

1. Your body temperature starts to rise above 37 °C because you are walking in the tropical sun and the air temperature is 45 °C. The sensors in your skin detect that your surface temperature is rising so you start to sweat and go red as blood flow in the capillaries under your skin increases. Your body attempts to lose heat.
2. A thermostat in a central heating system is a device that can sense the temperature. It switches a heating system on when the temperature decreases to a predetermined level, and off when it rises to another warmer temperature. So a room, a building, or a piece of industrial plant can be maintained within narrow limits of temperature.
3. Global temperature rises causing ice caps to melt. More water in the atmosphere means more clouds, more solar radiation is reflected by the clouds so global temperatures fall. But compare this with figure 1.3.14 which interprets it differently.

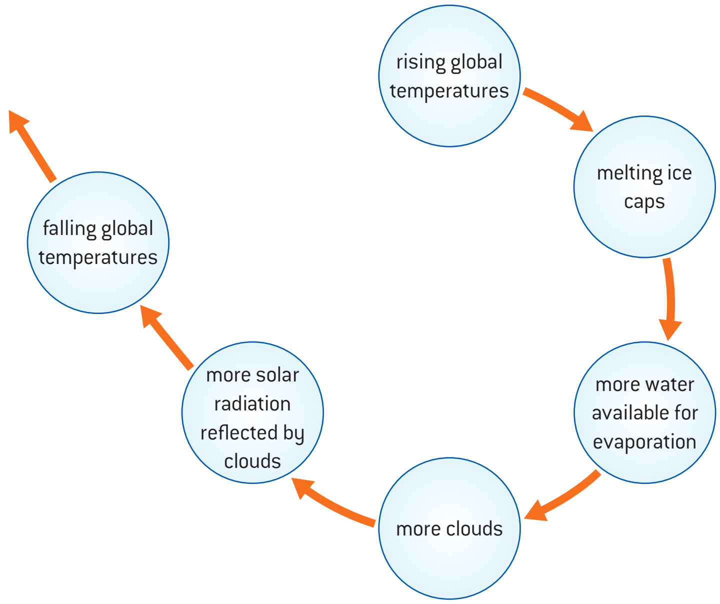



**Figure 1.3.12** Negative feedback dampening change

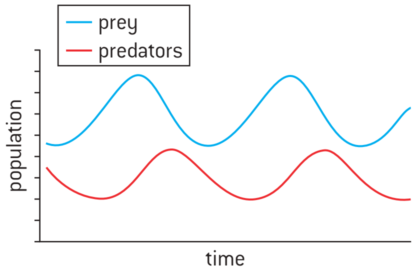



**Figure 1.3.13** Cycles of predator and prey in the Lotka–Volterra model

4. Predator–prey interactions. The Lotka–Volterra model (proposed in 1925 and 1926) is also known as the predator–prey model and shows the effect of changing numbers of prey on predator numbers. When prey populations (eg mice) increase, there is more food for the predator (eg owl) so they eat more and breed more, resulting in more predators which eat more prey so the prey numbers decrease. If there are fewer prey, there is less food and the predator numbers decrease. The change in predator numbers lags behind the change in prey numbers. The snowshoe hare and Canadian lynx is a well-documented example of this (see box, p36).
5. Some organisms have internal feedback systems, physiological changes occurring that prevent breeding when population densities are high, promoting breeding when they are low. It is negative feedback loops such as these that maintain 'the balance of nature'.

**Positive feedback** results in a further increase or decrease in the output that enhances the change in the system. It is destabilized and pushed to a new state of equilibrium. The process may speed up, taking ever-increasing amounts of input until the system collapses. Alternatively, the process may be stopped abruptly by an external force or factor. Positive feedback results in a 'vicious circle'.

## Examples of positive feedback

1. You are lost on a high snowy mountain. When your body senses that it is cooling below 37 °C, various mechanisms such as shivering help to raise your body core temperature again. But if these are insufficient to restore normal body temperature, your metabolic processes start to slow down, because the enzymes that control them do not work so well at lower temperatures. As a result you become lethargic and sleepy and move around less and less, allowing your body to cool even further. Unless you are rescued at this point, your body will reach a new equilibrium: you will die of hypothermia.
2. In some developing countries poverty causes illness and contributes to poor standards of education. In the absence of knowledge of family planning methods and hygiene, this contributes to population growth and illness, adding further to the causes of poverty: 'a vicious circle of poverty'.
3. Global temperature rises causing ice caps to melt. Dark soil is exposed so more solar radiation is absorbed. This reduces the **albedo** (reflecting ability of a surface) of Earth so global temperature rises. Compare this with figure 1.3.12 and you can see that the same change can result in positive or negative feedback. This is one reason that predicting climate change is so difficult.

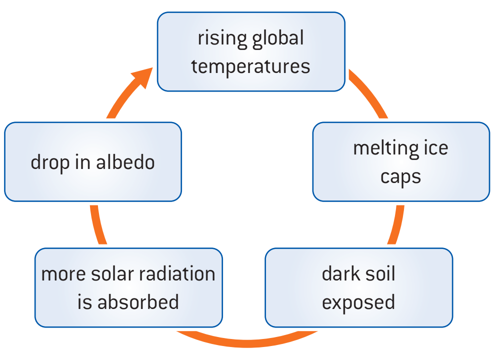



**Figure 1.3.14** Positive feedback in global warming

Whether a system is viewed as being in static or steady-state equilibrium may be a matter of the timescale. An ecosystem undergoing succession (see 2.4) is in a state of flux – it changes constantly. In succession, the system undergoes long-term changes. However, the system retains its long-term integrity, since it is functioning properly, in a balanced, natural way. A better way to describe this situation is that the system shows stability and all systems in nature show **stability** by default.

### Key term

**Positive feedback loops** (destabilizing) will tend to amplify changes and drive the system toward a tipping point where a new equilibrium is adopted.

Both natural and human systems are regulated by feedback mechanisms. Generally, we wish to preserve the environment in its present state, so negative feedback is usually helpful and positive feedback is usually undesirable. However there are situations where change is needed and positive feedback is advantageous, eg if students enjoy their Environmental Systems and Societies lessons, they want to learn more, so attend classes regularly and complete assignments. Consequently they move to a new equilibrium of being better educated about the environment.

We shall come back to feedback loops in various sections of this book, particularly in climate change and sustainable development.

## To do

**Predator–prey interactions and negative feedback**

**Figure 1.3.15** Canadian lynx chasing snowshoe hare

The Hudson Bay Trading Company in Northern Canada kept very careful records of pelts (skins) brought in and sold by hunters over almost a century. This is a classic set of data and shows this relationship because the hare is the only prey of the lynx and the lynx its only predator. Usually things are more complicated.

Figure 1.3.16 (adapted from Odum, *Fundamentals of Ecology*, Saunders, 1953) shows a plot of that data.

We have to assume that the numbers of animals trapped were small compared to the total populations and that the numbers trapped were roughly proportional to total population numbers. Also assumed is the prey always has enough food so does not starve. Given that, the cycles are remarkably constant with the lynx populations always smaller than and lagging behind the hare ones.

1. On average, what was the cycle length of the lynx population?
2. On average, what was the cycle length of the hare population?
3. Why do lynx numbers lag behind hare numbers?
4. Why are lynx numbers smaller than hare numbers?

Things are never as straightforward in ecology as we expect though. In regions where lynx died out, hare populations still continued to fluctuate. Why do you think this was?

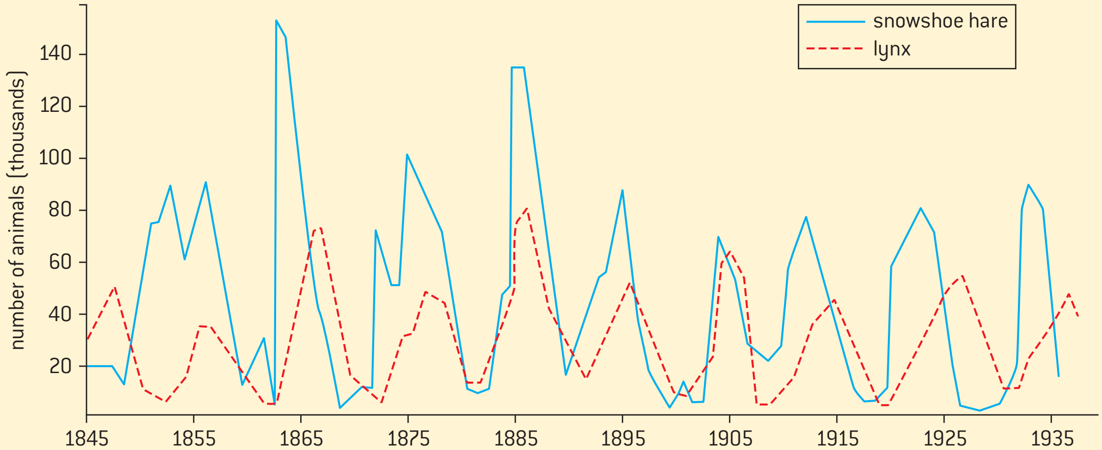



**Figure 1.3.16** Snowshoe hare and Canadian lynx population numbers from 1845 to 1940

## To do

Here are a number of examples of how both positive and negative feedback mechanisms might operate in the physical environment. No one can be sure which of these effects is likely to be most influential, and consequently we cannot know whether or not the Earth will manage to regulate its temperature, despite human interference with many natural processes.

Label each example as either positive or negative feedback.

Draw diagrams of one example of positive feedback and one example of negative feedback using the examples given, to show how feedback affects a system. Include feedback loops on your diagrams.

1. As carbon dioxide levels in the atmosphere rise the temperature of the Earth rises.

   As the Earth warms the rate of photosynthesis in plants increases, more carbon dioxide is therefore removed from the atmosphere by plants, reducing the greenhouse effect and reducing global temperatures.

2. As the Earth warms:

   Ice cover melts, exposing soil or water.

   Albedo decreases (albedo is the fraction of light that is reflected by a body or surface).

   More energy is absorbed by Earth's surface.

   Global temperature rises.

   More ice melts.

3. As Earth warms, upper layers of permafrost melt, producing waterlogged soil above frozen ground.

   Methane gas is released in an anoxic environment.

   The greenhouse effect is enhanced.

   Earth warms, melting more permafrost.

4. As Earth warms, increased evaporation produces more clouds.

   Clouds increase albedo, reflecting more light away from Earth.

   Temperature falls.

   Rates of evaporation fall.

5. As Earth warms, organic matter in soil is decomposed faster:

   More carbon dioxide is released.

   Enhanced greenhouse effect occurs.

   Earth warms further.

   Rates of decomposition increase.

6. As Earth warms, evaporation increases:

   Snowfall at high latitudes increases.

   Icecaps enlarge.

   More energy is reflected by increased albedo of ice cover.

   Earth cools.

   Rates of evaporation fall.

7. As Earth warms, polar icecaps melt releasing large numbers of icebergs into oceans.

   Warm ocean currents such as Gulf Stream are disrupted by additional freshwater input into ocean.

   Reduced transfer of energy to poles reduces temperature at high latitudes.
   Ice sheets reform and icebergs retreat.

   Warm currents are re-established.

## Resilience of systems

The resilience of a system measures how it responds to a disturbance. The more resilient a system, the more disturbance it can deal with. Resilience is the ability of a system to return to its initial state after a disturbance. If it has low resilience, it will enter a new state – see figure 1.3.17.

Resilience is generally considered a good thing, whether in a society, individual or ecosystem as it maintains stability of the system.

In eucalypt forests of Australia, fire is seen as a major hazard. But eucalypts have evolved to survive forest fires. Their oil is highly flammable and the trees produce a lot of litter which also burns easily. But the trees regenerate quickly after a fire because they have buds within their trunks

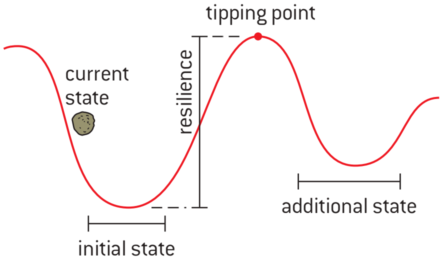



Figure 1.3.17 Resilience can be modelled as a ball in a bowl. If the ball is pushed upwards, it returns to the bottom of the bowl – its initial state. But if it is pushed enough, it will leave the bowl and settle elsewhere – in an additional state. The higher the walls of the bowl, the more resilience the system has as the more energy you need to push it out of the bowl

and plants that would have competed with them are destroyed. The eucalypts are resilient. But when the indigenous eucalypts are replaced by tree species that cannot withstand fire, it can be devastating.

In managed systems, such as agriculture, we want stability so we can predict that the amount of food we grow is about the same each year. If this does not happen, there can be disastrous consequences, for example the Irish potato famine or the Sahel drought and famine.

But resilience is not always good, eg a pathogenic bacterium causing a fatal disease could be very resilient to antibiotics which means it will kill many people so, in this case, its resilience is not so good for us.

## Factors affecting ecosystem resilience

- The more diverse and complex an ecosystem, the more resilient it tends to be as there are more interactions between different species.
- The greater the species biodiversity of the ecosystem, the greater the likelihood that there is a species that can replace another if it dies out and so maintain the equilibrium.
- The greater the genetic diversity within a species, the greater the resilience. A monoculture of wheat or rice can be wiped out by a disease if none of the plants have resistance which is more likely in a diverse gene pool.
- Species that can shift their geographical ranges are more resilient.
- The larger the ecosystem, the more resilience as animals can find each other more easily and there is less edge-effect.
- The climate affects resilience – in the Arctic, regeneration of plants is very slow as the low temperatures slow down photosynthesis and so growth. In the tropical rain forests, growth rates are fast as light, temperature and water are not limiting.
- The faster the rate at which a species can reproduce means recovery is faster. So r-strategists (2.4) with a fast reproductive rate can recolonize the system better than slowly reproducing K-strategists.
- Humans can remove or mitigate the threat to the system (eg remove a pollutant, reduce an invasive species) and this will result in faster recovery.

## Tipping points

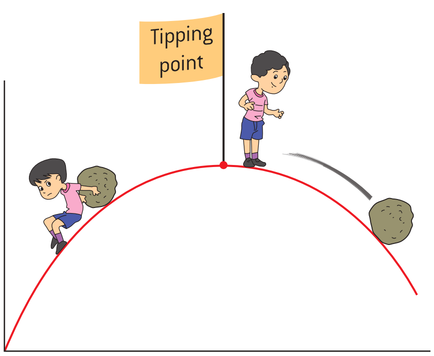



Figure 1.3.18 Illustrating a tipping point

Small changes occur in systems and may not make a huge difference. But when these changes tip the equilibrium over a threshold, known as a tipping point, the system may transform into a very different one. Then positive feedback loops drive the system to a new steady state.

An ecological **tipping point** is reached when an ecosystem experiences a shift to a new state in which there are significant changes to its biodiversity and the services it provides.

Characteristics of tipping points:

- They involve positive feedback which makes the change self-perpetuating; eg deforestation reduces regional rainfall, which increases fire risk, which causes forest dieback.

- There is a threshold beyond which a fast shift of ecological states occurs.
- The threshold point cannot be precisely predicted.
- The changes are long-lasting.
- The changes are hard to reverse.
- There is a significant time lag between the pressures driving the change and the appearance of impacts, creating great difficulties in ecological management.

## Examples of tipping points

1. **Lake eutrophication –** if nutrients are added to a lake ecosystem, it may not change much until enough nutrients are added to shift the lake to a new state – then plants grow excessively, light is blocked by decomposing plant material, oxygen levels fall and animals die. The lake becomes eutrophic and it takes a great effort to restore it to the previous state (4.4).
2. **Extinction of a keystone species** (eg elephants) from a savanna ecosystem can transform it to a new state which cannot be reversed.
3. **Coral reef death –** if ocean acidity levels rise enough, the reef coral dies and cannot regenerate.

Tipping points are well-known in local or regional ecosystems but there is debate about whether we are reaching a global tipping point. Some people say that climate change caused by human activities will force the Earth to a new, much warmer state – as much as 8 °C warmer than today. But evidence is that we see warming in one region and cooling in others, wetter in some and drier in others. The global system is so complex and ecosystems respond differently, often independently of other ecosystems.

If there were to be global tipping points, there are major implications for decision-makers. Some may think that below this point, not much would change while, once it is reached, all is lost as society could not respond fast enough. That could lead to inaction or despair – the 'what's the point, there is nothing we can do now' point of view.

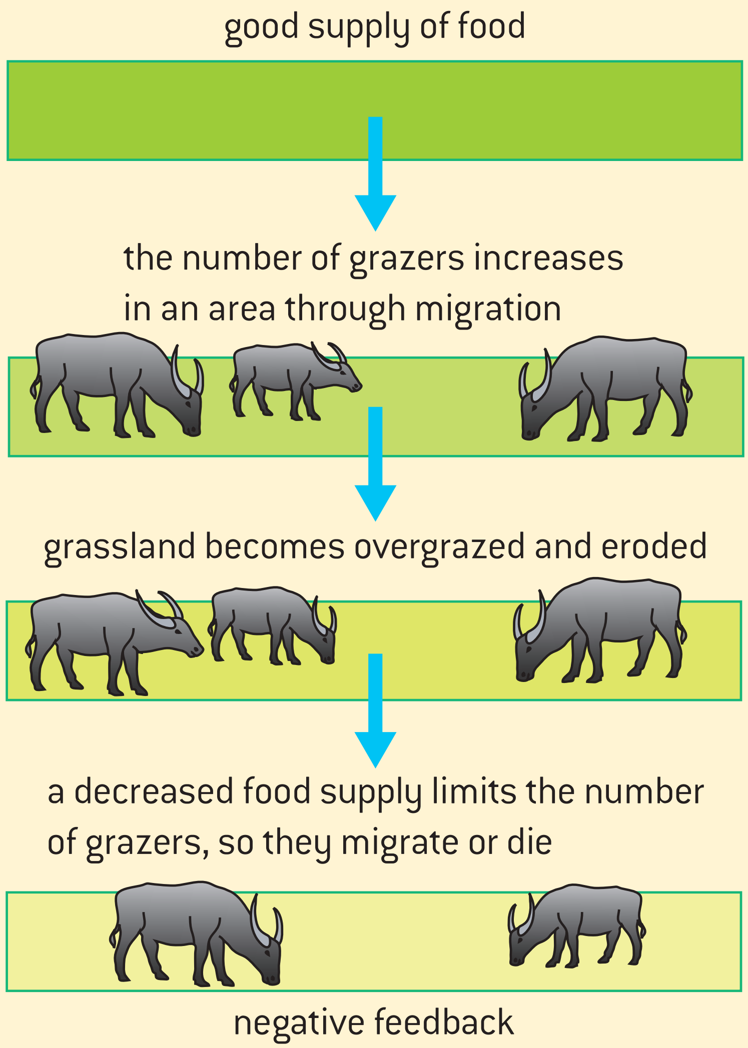
The best approach we can have may be the precautionary one where we don't know what will happen exactly but can take steps to modify what we do in case. Such risk management is the responsible route to take.

### Practical Work

* Create a model of a feedback loop.
* Create a model of a food web.

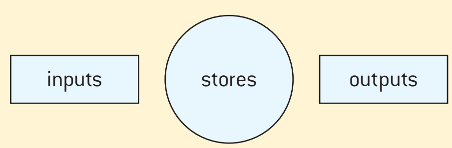
## To do

1. Negative and positive feedback control. Look at this example of feedback control.
   a) How is the growth of the animal population regulated in the diagram?
   b) Explain why it is an example of negative feedback control.




▲ **Figure 1.3.19** Negative feedback amongst grazing animals

2. Explain with a named example how positive feedback may contribute to global warming.
3. Complete the diagram of a generalized ecosystem showing inputs, outputs and stores. Remember to add in human activities.



# 1.4 Sustainability

## Significant ideas:

- All systems can be viewed through the lens of sustainability.
- Sustainable development meets the needs of the present without compromising the ability of future generations to meet their own needs.
- Environmental indicators and ecological footprints can be used to assess sustainability.
- Environmental Impact Assessments (EIAs) play an important role in sustainable development.

## Applications and skills:

- **Explain** the relationship between natural capital, natural income and sustainability.
- **Discuss** the value of ecosystem services to a society.
- **Discuss** how environmental indicators can be used to evaluate the progress of a project to increase sustainability, eg Millennium Ecosystem Assessment.
- **Evaluate** the use of EIAs.
- **Explain** the relationship between ecological footprint (EF) and sustainability.

## Knowledge and understanding:

- **Sustainability** is the use and management of resources that allows full natural replacement of the resources exploited and full recovery of the ecosystems affected by their extraction and use.
- **Natural capital** is a term used for natural resources that can produce a sustainable natural income of goods or services.
- **Natural income** is the yield obtained from natural resources
- Ecosystems may provide life-supporting services such as water replenishment, flood and erosion protection, and goods such as timber, fisheries and agricultural crops.
- Factors such as biodiversity, pollution, population or climate may be used quantitatively as environmental indicators of sustainability. These factors can be applied on a range of scales from local to global. The **Millennium Ecosystem Assessment** gave a scientific appraisal of the condition and trends in the world's ecosystems and the services they provide using environmental indicators, as well as the scientific basis for action to conserve and use them sustainably.
- **Environmental Impact Assessments** (EIAs) incorporate baseline studies before a development project is undertaken. They assess the environmental, social and economic impacts of the project, predicting and evaluating possible impacts and suggesting mitigation strategies for the project. They are usually followed by an audit and continued monitoring. Each country or region has different guidance on the use of EIAs.
- EIAs provide decision makers with information in order to consider the environmental impact of a project. There is not necessarily a requirement to implement an EIA's proposals and many socio-economic factors may influence the decisions made.
- Criticisms of EIAs include the lack of a standard practice or training for practitioners, the lack of a clear definition of system boundaries and the lack of inclusion of indirect impacts.
- An **ecological footprint** (EF) is the area of land and water required to sustainably provide all resources at the rate at which they are being consumed by a given population. Where the EF is greater than the area available to the population, this is an indication of unsustainability.

*'The ultimate test of a moral society is the kind of world that it leaves to its children.'*

Dietrich Bonhoeffer, German theologian

*'He who slaughters his cows today shall thirst for milk tomorrow.'*

Muslim proverb

## Key terms

**Sustainability** is the use and management of resources that allows full natural replacement of the resources exploited and full recovery of the ecosystems affected by their extraction and use.

The term **'sustainable development'** has been defined as 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs.' (From *Our Common Future*, the report of the World Commission on Environment and Development, 1987).

# Sustainability

Sustainability means living within the means of nature, on the 'interest' or sustainable natural income generated by natural capital. But sustainability is a word that means different things to different people. Economists have a different view from environmentalists about what sustainable means. The word sustainable is often used as an adjective in front of words such as resource, development and population.

Any society that supports itself in part by depleting essential forms of natural capital is unsustainable. There is a finite amount of materials on Earth and we are using much of it unsustainably – living on the capital as well as the interest. Our societies and economies cannot grow or make progress outside of environmental limits (figure 1.4.1).

## Ecological overshoot

According to UN data (figure 1.4.1) humanity has overshot its sustainable level of resource exploitation.

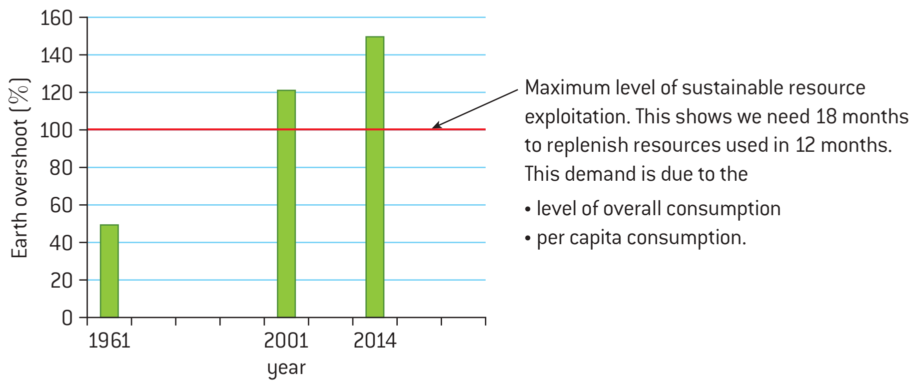



**Figure 1.4.1** Ecological overshoot

It is more in some parts of the world and cannot continue indefinitely.

## Sustainability indicators

How we measure sustainability is crucial and there are many indices we can use together, both ecological and socio-economic. These could be anything from air quality, environmental vulnerability and water poverty to US$ GDP (Gross Domestic Product) per capita, life expectancy or gender parity. We can also measure sustainability on scales from local to global. The smaller the scale, the more accurate it can be but we also need a global measurement to get the whole picture.

## To think about

The **Millennium Ecosystem Assessment (MEA)**, funded by the UN and started in 2001, is a research programme that focuses on how ecosystems have changed over the last decades and predicts changes that will happen. In 2005, it released the results of its first four-year study of the Earth's natural resources. It was not happy reading.

The report said that natural resources (food, freshwater, fisheries, timber, air) are being used in ways that degrade them so make them unsustainable in the longer term.

Key facts reported are:

- 60% of world ecosystems have been degraded.
- About 25% of the Earth's land surface is now cultivated.
- We use 40–50% of all available surface freshwater and water withdrawals from underground sources have doubled over the past 40 years
- Over 25% of all fish stocks are overharvested.
- Since 1980, about 35 % of mangroves have been destroyed.
- About 20% of corals have been lost in 20 years and another 20% degraded.
- Nutrient pollution has led to eutrophication of waters and dead coastal zones.
- Species extinction rates are now 100–1,000 times above the background rate.
- We have had more effect on the ecosystems of Earth in the last 50 years than ever before.

Some recommendations were to:

- Remove subsidies to agriculture, fisheries and energy sources that harm the environment.
- Encourage landowners to manage property in ways that enhance the supply of ecosystem services, such as carbon storage and the generation of fresh water.
- Protect more areas from development, especially in the oceans.

## To think about

Using the figure below think about the following questions. Are you optimistic or pessimistic about the results of the impact of humans on the Earth?

What evidence are you using for your decision?

If you had the power, what actions would you force governments to take now to safeguard the environment but also protect humans from suffering? Give your reasons.

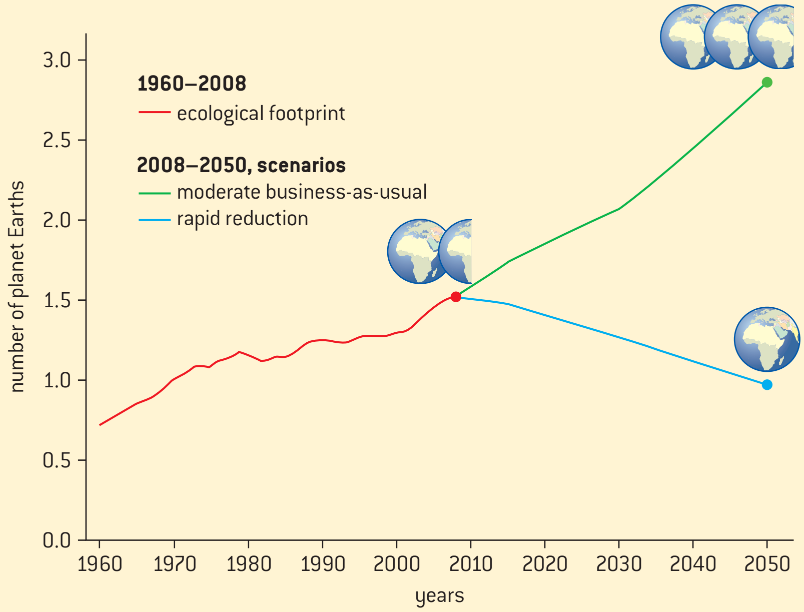



**Figure 1.4.2**

But how can we change?

You may wonder why this continues if we all know it to be so. It is perhaps due to many factors including:

- Inertia: when changing what we do seems too difficult.
- The result of the '**tragedy of the commons**' (4.3), when many individuals act in their own self-interest to harvest a resource but destroy the long-term future of that resource so there is none for anyone. It may be obvious that this will happen, but each individual benefits from taking the resource in the short term so they continue to do so. For example, hunting an endangered species may result in its extinction but if your family are starving and it is the only source of food, you will probably hunt it to eat it.

Some people think that the real worth of natural capital is about the same as the value of the gross world product (total global output) – about US$65 trillion per year, yet we are only just beginning to give economic value to soil, water and clean air and to measure the cost of loss of biodiversity (see Topic 8).

## Natural capital and natural income

Capital is what economists term the means of production – factories, tools, machines – and is used to create goods which provide income.

Natural capital is the goods and services that the environment provides humans with in order to provide natural income. For example, a forest (natural capital) provides timber (natural income); a shoal of fish or an agricultural crop provides food for us. Natural capital also provides services, for example erosion control, water management, recycling waste. See in more detail in Topic 8.

**Key terms**

**Natural capital** is a term used for natural resources that can produce a sustainable **natural income** of goods or services.

**To think about**

*The Millennium Development Goals*
http://www.undp.org/mdg/
The Millennium Development Goals (MDGs) are eight goals to be achieved by 2015 that respond to the world's main development challenges. The MDGs are drawn from the actions and targets contained in the **Millennium Declaration** that was adopted by 189 nations and signed by 147 heads of state and governments during the **UN Millennium Summit** in September 2000.
Goal 1: Eradicate extreme poverty and hunger
Goal 2: Achieve universal primary education
Goal 3: Promote gender equality and empower women
Goal 4: Reduce child mortality
Goal 5: Improve maternal health
Goal 6: Combat HIV/AIDS, malaria and other diseases
Goal 7: Ensure environmental sustainability
Goal 8: Develop a Global Partnership for Development
Are we on target to reach these goals? Research what actions have been taken since 2000. (Try searching the web for Millenium Development Goals BBC and you should find some BBC webpages with an update.)
Do you think these were attainable goals or too ambitious?

## Environmental impact assessments

An environmental impact assessment or EIA is a report prepared **before** a development project to change the use of land, for example to plant a forest or convert fields to a golf course. An EIA weighs up the relative advantages or disadvantages of the development. It is therefore necessary to establish how the abiotic environment and biotic community would change if a development scheme went ahead. An EIA will try to quantify changes to microclimate, biodiversity, scenic and amenity value resulting from the proposed development. These measurements represent the production of a **baseline** study.

EIAs look at what the environment is like now and forecast what may happen if the development occurs. Both negative and positive impacts are considered as well as other options to the proposed development. While often EIAs have to deal with questions about the effect on the natural environment they can also consider the likely effects on human populations. This is especially true where a development might have an effect on human health or have an economic effect for a community.

## What are EIAs used for?

EIAs are often, though not always, part of the planning process that governments set out in law when large developments are considered. They provide a documented way of examining environmental impacts that can be used as evidence in the decision-making process of any new development. The developments that need EIAs differ from country to country, but certain types of developments tend to be included in the EIA process in most parts of the world. These include:

- major new road networks
- airport and port developments
- building power stations
- building dams and reservoirs
- quarrying
- large-scale housing projects.

## Where did EIAs come from?

In 1969, the US Government passed the National Environmental Policy Act (NEPA). NEPA made it a priority for federal agencies to consider the natural environment in any land use planning. This gave the natural environment the same status as economic priorities. Within 20 years of NEPA becoming law in the US, many other countries also included EIAs as part of their planning policy. In the US, environmental assessments (EA) are carried out to determine if an EIA (called EIS – environmental impact statement) needs to be undertaken and filed with the federal agencies.

## What does an EIA need in it?

There is no set way of conducting an EIA, but various countries have minimum expectations of what should be included in an EIA. It is possible to break an assessment down into three main tasks:

- Identifying impacts (scoping).
- Predicting the scale of potential impacts.
- Limiting the effect of impacts to acceptable limits (mitigation).

There is always a non-technical summary so that the general public can understand the issues.

## Weaknesses of EIAs

Different countries have different standards for EIAs which makes it hard to compare them. Also, it is hard to determine where the boundary of the investigation should be. How large an area, how many variables, how much does the EIA cost? It is also very difficult to consider all indirect impacts of a development so some may be missed.

### To think about

EIAs are models of the system under study and allow us to predict the effects of the proposed change. A model is only as good as its parameters and asking the right questions is crucial. A change of land use will always have an effect but whether this is a net positive or negative one depends on the criteria used to measure it. Simplistically, if a factory blocks your view of the mountains that may be a loss to you but it may bring employment to the area, produce goods that would otherwise be imported and reduce the country's ecological footprint.

Cost-benefit analysis measures impacts of a development or change of land use translated into monetary values. In theory, this puts all costs into the same units of measure – money – so they can be assessed. Of course, how the assessment is made is critical to the values assigned and there are several ways to do this. For example, it may be based on the cost of restoring the environment to its previous state (eg after an open cast mine operation) or ask people which of several options they would select or be prepared to pay for.

Strategic environmental assessment tries to measure the social and environmental costs of a development but this can be subjective or a not very accurate prediction. Does it also depend on the environmental worldview of those planning the assessment?

Imagine a development or change of land use in an area near to your school or home. Decide amongst your class what this will be (it may be an actual one that is about to happen or has happened) and discuss:

- What criteria you would use to select the factors you think will change (eg number of jobs provided, net profit, land degradation, habitat loss, pollution).
- How you value these (is there another way of measuring them apart from financial?)
- How you weigh up the evidence to make a decision on whether the project should proceed or proceed in a modified state.

### Practical Work

* Investigate what Ecological Footprint modelling can tell us about resource use.
* Consider whether sustainable development is a term that contradicts itself.
* Can sustainability agreements only be international? What is the point of a nation being sustainable if the rest of the world is not?

### Key term

An **ecological footprint (EF)** is the area of land and water required to sustainably provide all resources at the rate at which they are being consumed by a given population.

## Ecological footprints

**EF** is a **model** used to estimate the demands that human populations place on the environment. The measure takes into account the area required to provide all the resources needed by the population, and the assimilation of all wastes. Where the EF is greater than the area available to the population, this is an indication of unsustainability as the population exceeds the carrying capacity (8.4) of the area.

EFs may vary significantly from country to country and person to person and include aspects such as lifestyle choices (EVS), productivity of food production systems, land use and industry.

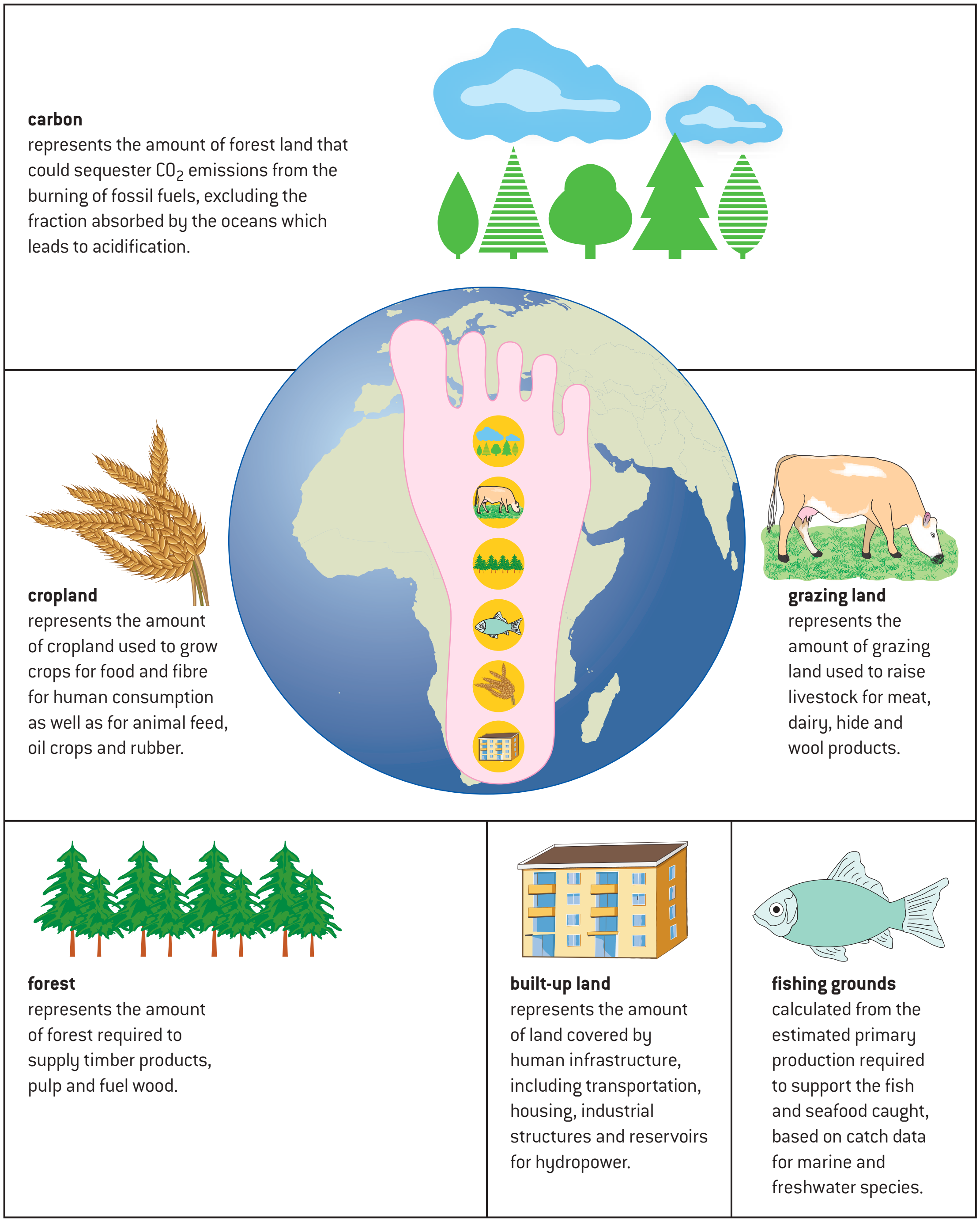



**Figure 1.4.3** Ecological footprint (EF) (© WWF)

# 1.5 Humans and pollution

## Significant ideas:

- Pollution is a highly diverse phenomenon of human disturbance in ecosystems.
- Management strategies can be applied at different levels.

## Applications and skills:

- **Construct** systems diagrams to show the impact of pollutants.
- **Evaluate** the effectiveness of each of the three different levels of intervention, with reference to figure 1.5.6.
- **Evaluate** the use of DDT.

## Knowledge and understanding:

- Pollution is the addition of a substance or an agent to an environment by human activity, at a rate greater than that at which it can be rendered harmless by the environment, and which has an appreciable effect on the organisms in the environment.
- Pollutants may be in the form of organic/inorganic substances, light, sound or heat energy, or biological agents/invasive species, and derive from a wide range of human activities including the combustion of fossil fuels.
- Pollution may be non-point or point source, persistent or biodegradable, acute or chronic.
- Pollutants may be primary (active on emission) or secondary (arising from primary pollutants undergoing physical or chemical change).
- Dichlorodiphenyltrichloroethane (DDT) exemplifies a conflict between the utility of a 'pollutant' and its effect on the environment.

### Key term

**Pollution** is the addition of a substance or an agent to an environment by human activity, at a rate greater than that at which it can be rendered harmless by the environment, and which has an appreciable effect on the organisms within it.


**Figure 1.5.1** Does the earth need a gas mask?

## Pollutants and pollution

Pollutants are released by human activities and may be:

- matter (gases, liquids or solids) which is organic (contains carbon atoms) or inorganic
- energy (sound, light, heat)
- living organisms (invasive species or biological agents).

There are:

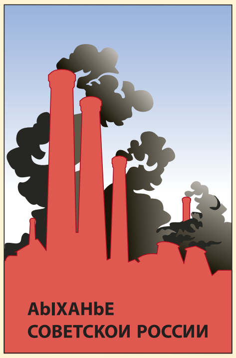
- **primary pollutants** which are active on emission eg carbon monoxide from the incomplete combustion of fossil fuels, which causes headaches and fatigue and can kill
- **secondary pollutants** which are formed by primary pollutants undergoing physical or chemical changes eg sulphuric acid forms when sulphur trioxide reacts with water.

Photochemical smog is a mixture of primary and secondary pollutants (see sub-topic 6.3).

Since humans have been on Earth, we have polluted to a greater or lesser extent. Sewage and waste are products of human communities and burning wood and then coal has caused air pollution for 1,000 years. When population levels were lower, the environment could cope with these pollutants. However, pollution may be an inevitable side-effect of the economic development that has given most humans a far higher standard of living than we would otherwise have had. Since the Industrial Revolution pollution has increased but how we deal with it has also improved as we monitor industries and legislate against excessive pollution.

## To think about

It is sometimes said that a pollutant is a substance in the wrong place, in the wrong amount or at the wrong time. Could this be true of carbon dioxide, ozone or nitrate?




▲ **Figure 1.5.2** Poster from the USSR before 1950 encouraging production by saying that the smoke from chimneys is the breath of Soviet Russia

## Major sources of pollutants

Figure 1.5.3 lists some major sources of pollutants. We shall be considering some of these later on.

| Major source | Pollutant | Effect |
|---|---|---|
| **Combustion of fossil fuels** | Carbon dioxide | Greenhouse gas – climate change |
| | Sulphur dioxide | Acid deposition – tree and fish death, respiratory disease in humans |
| | Nitrogen oxides | Respiratory infections, eye irritation, smog |
| | Photochemical smog including tropospheric ozone, PANs, VOCs (volatile organic compounds) | Secondary pollutants (formed from others in the atmosphere) – damage to plants, eye irritation, respiratory problems in humans |
| | Carbon monoxide | Binds with haemoglobin in red blood cells instead of oxygen – can lead to death by suffocation |
| **Domestic waste** | Organic waste (food and sewage) | Eutrophication, waterborne diseases |
| | Waste paper | Volume fills up landfill sites, forests cut to produce it |
| | Plastics – containers, packaging | Volume fills up landfill sites, derived from oil |
| | Glass | Energy required to manufacture it (as with all products), can be recycled but most goes into landfill sites |
| | Tins/cans | Can be recycled but also goes into landfill |
| **Industrial waste** | Heavy metals | Poisoning, eg mercury, lead, cadmium |
| | Fluorides | Poisoning |
| | Heat | Reduces solubility of gases in water, so less oxygen so organisms may die |
| | Lead | Disabilities in children |
| | Acids | Corrosive |
| **Agricultural waste** | Nitrates | Eutrophication |
| | Organic waste | Eutrophication, disease spread |
| | Pesticides | Accumulate up food chains |

▲ **Figure 1.5.3** Major sources of pollutants and their effects

## Point source and non-point source pollutants

Non-point source (NPS) pollution:

- Is the release of pollutants from numerous, widely dispersed origins, for example gases from the exhaust systems of vehicles, chemicals spread on fields.
- May have many sources and it may be virtually impossible to detect exactly where it is coming from.
- Rainwater can collect nitrates and phosphates which are spread as fertilizer as it infiltrates the ground or as runoff on the surface. It may travel many kilometres before draining into a lake or river and increasing the concentration of nitrates and phosphates so much that eutrophication occurs. It would not be possible to say which farmer spread the excess fertilizer.
- Air pollution can be blown hundreds of kilometres and chemicals released from open chimneys mix with those from others.

So one solution is to set limits for all farmers and all industries to reduce emissions and then monitor what they actually do.

Point source (PS) pollution:

- Is the release of pollutants from a single, clearly identifiable site, for example a factory chimney or the waste disposal pipe of a sewage works into a river.
- Is easier to see who is polluting – a factory or house.
- Is usually easier to manage as it can be found more easily.


▲ **Figure 1.5.4**

**Practical Work**

- Create a poster/website/wiki on the benefits and disadvantages of using DDT.
- Construct a systems diagram to show pollution of a local ecosystem.

## Persistent organic pollutants (POPs) and biodegradable pollutants

**POPs** were often manufactured as pesticides in the past. They are resistant to breaking down and remain active in the environment for a long time. Because of this, they bioaccumulate in animal and human tissues and biomagnify in food chains (see 2.2) and can cause significant harm.

Examples of these are DDT (see 2.2), dieldrin, chlordane and aldrin. Other POPs are polyvinyl chloride (PVC), polychlorinated biphenyls (PCBs) and some solvents. They have similar properties:

- high molecular weight
- not very soluble in water
- highly soluble in fats and lipids – which means they can pass through cell membranes
- halogenated molecules, often with chlorine.

PCBs were widely used in electrical apparatus and as coolants since the 1930s but banned by 2001. They cause cancers and disrupt hormone functions and have a similar structure and action in animals to dioxin which is one of the most deadly chemicals that humans have made. Because they are so persistent, PCBs are found everywhere in water as well as in animal tissues, even in the Arctic Circle.

**Biodegradable pollutants** do not persist in the environment and break down quickly. They may be broken down by decomposer organisms or physical processes, eg light or heat. Examples are soap, domestic sewage, degradable plastic bags made of starch. One common herbicide is glyphosate which farmers use to kill weeds. It is degraded and broken down by soil organisms.

## Acute and chronic pollution

Acute pollution is when large amounts of a pollutant are released, causing a lot of harm. An example of this was when the chemical aluminium sulphate was accidently tipped into the wrong place in a water treatment works in Cornwall in the UK in 1988 and many people drank water which poisoned them. Another example was in the Bhopal Disaster of 1984 in India (1.1).

Chronic pollution results from the long-term release of a pollutant but in small amounts. It is serious because:

- often it goes undetected for a long time
- it is usually more difficult to clean it up
- it often spreads widely.

Air pollution is often chronic causing non-specific respiratory diseases, for example asthma, bronchitis, emphysema. Beijing's poor air quality is an example of chronic air pollution.

▲ **Figure 1.5.5** Chronic air pollution in Beijing 2014

### To think about

**The Prisoner's Dilemma**

A big question about us is whether we are, by nature, loving or aggressive, noble or selfish, nice or nasty. Do we not steal or cheat because we may be found out or because we know it is wrong. Is it our default position to be kind and helpful to each other or to be top even if, or particularly if, it hurts someone else? Scientists, sociologists, philosophers, politicians and all thinking people want to know about our innate nature and why we react as we do.

There is a type of game that you can play as an example of Game Theory and it is called the Prisoner's Dilemma. Here is a version of it.

Two people A and B are suspected of a crime and arrested. There is not enough evidence to convict them unless they confess. The police separate them and offer each one the same deal. If one admits that they both did the crime and betrays the other, that one goes free and the other goes to prison for 10 years. If both stay silent, they both go to prison for a year. If both confess, they both go to prison for 5 years. What should they do? The best scenario for one is to confess and the other stays silent. But they don't know what the other will do. What has this to do with pollution? Quite a lot.

The best economic scenario for a polluter is to keep polluting as long as he/she is not found out. Not to confess. The cost of the pollution is then shared between everyone and the polluter does not have to spend money reducing their own personal or business pollution. If the polluter confesses, they may be punished by a fine, imprisonment or having to spend money in reducing the pollution.

But, just as in the Prisoner's Dilemma, while keeping silent and polluting is fine in the short term, in the longer term, the best scenario is 'tit for tat' – if I cooperate with you – stop polluting, you will cooperate with me – stop polluting too and the world will be a cleaner place – we both gain. If we keep betraying each other, we will both be losers at the end. And that is where we are with pollution. If we pollute with NPS pollutants, we are unlikely to be found out and everyone pays for the clean up. An individual, company or country can gain from non-compliance in the short term if the others comply.

But what will happen in the long term?

Think of two particular types of pollution (one in the atmosphere and one in water) that could be examples of NPS pollution.

What does this mean for international agreements on pollution?

## Detection and monitoring of pollution

Pollution can be measured directly or indirectly.

Direct measurements record the amount of a pollutant in water, the air or soil.

Direct measurements of air pollution include measuring:

- the acidity of rainwater
- amount of a gas, for example carbon dioxide, carbon monoxide, nitrogen oxides in the atmosphere
- amount of particles emitted by a diesel engine
- amount of lead in the atmosphere.

Direct measurements of water or soil pollution include testing for:

- nitrates and phosphates
- amount of organic matter or bacteria
- heavy metal concentrations.

Indirect measurements record changes in an abiotic or biotic factor which are the result of the pollutants. Indirect measurements of pollution include:

- measuring abiotic factors that change as a result of the pollutant (eg oxygen content of water)
- recording the presence or absence of indicator species – species that are only found if the conditions are either polluted (eg rat-tailed maggot in water) or unpolluted (eg leafy lichens on trees).

## Pollution management strategies

Pollution can be managed in three main ways:

- by changing the human activity which produces it
- by regulating or preventing the release of the pollutant or
- by working to clean up or restore damaged ecosystems.

The pollution management model in Figure 1.5.6 lists the actions available in each category of management and will be referred to throughout the book when specific pollutants are considered.

| Process of pollution | Level of pollution management |
|---|---|
| HUMAN ACTIVITY PRODUCING POLLUTANT<br>↓ | **Altering human activity**<br>The most fundamental level of pollution management is to change the human activity that leads to the production of the pollutant in the first place, by promoting alternative technologies, lifestyles and values through:<br>• campaigns<br>• education<br>• community groups<br>• governmental legislation<br>• economic incentives/disincentives. |

| | |
|---|---|
| RELEASE OF POLLUTANT INTO ENVIRONMENT ↓ | **Controlling release of pollutant**<br>Where the activity/production is not completely stopped, strategies can be applied at the level of regulating or preventing the release of pollutants by:<br>• legislating and regulating standards of emission<br>• developing/applying technologies for extracting pollutant from emissions. |
| IMPACT OF POLLUTANT ON ECOSYSTEMS | **Clean-up and restoration of damaged systems**<br>Where both the above levels of management have failed, strategies may be introduced to recover damaged ecosystems by:<br>• extracting and removing pollutant from ecosystem<br>• replanting/restocking lost or depleted populations and communities |

▲ **Figure 1.5.6** Pollution management targeted at three different levels

CASE STUDY

## DDT and malarial mosquitoes

▲ **Figure 1.5.7** Malarial mosquito sucking blood from a human

In 1970, the WHO (World Health Organization) banned the use of DDT, a persistent organochlorine insecticide. It is still used in some countries in the tropics but in small quantities for spraying inside houses to kill the malarial mosquito, *Anopheles*, which is the vector for malarial parasites.

The question is whether banning DDT did more harm than good.

It is believed that malaria kills 2.7 million people a year, mostly children under the age of five, and infects 300–500 million a year. It is also thought that DDT prevented millions of deaths due to malaria. So why the ban? In her book, *Silent Spring*, Rachel Carson discusses the effect of DDT on birds of prey in thinning their eggshells and reducing their population numbers. But some say that evidence was slight for bird egg shell thinning and DDT is an effective insecticide against the malarial mosquito.

The manufacture and use of DDT was banned in the US in 1972, on the advice of the US Environmental Protection Agency. The use of DDT has since been banned in most other MEDCs, but it is not banned for public health use in most areas of the world where malaria is endemic. DDT was recently exempted from a proposed worldwide ban on organophosphate chemicals. DDT for malarial control involves spraying the walls and backs of furniture, so as to kill and repel adult mosquitoes that may carry the malarial parasite. Although other chemicals could be used, DDT is cheap and persistent and good at the job. Outside DDT is not used because of its persistence and toxicity. Also, its persistence means that mosquitoes become resistant (the ones that survive, breed and develop a population of resistant mosquitoes).

Malaria incidence is increasing, partly due to resistance, partly to changes in land use and migration of people to areas where malaria is endemic. In treating the cause, DDT use is just one tool along with other chemicals, mosquito nets and removal of stagnant water where mosquitoes breed.

There is hyperbole, bias and misinformation in the debate on DDT but malaria probably does not receive enough funding for research as it is mostly a disease of the poor.

### To do

Do your own research on DDT. What evidence can you find for both sides of the argument?

Be careful in looking at sources. Are they biased? Can they substantiate their claims?

Do you now think that DDT should have been banned or should still be used?

State the environmental value system that you identify in your choice of lifestyle and how sustainable it is.

Explain how your own environmental value system compares with others.

# BIG QUESTIONS

## Foundations of environmental systems and societies

Examine in what ways might the solutions explored in the pollution management model alter your predictions for our future.

Discuss what are the strengths and weaknesses of using models to assess sustainability.

## Reflective questions

- Environmental value systems shape the way we perceive the environment. What other value systems shape the way we view the world?
- Models are a simplified construction of reality. In the construction of a model, how can we know which aspects of the world to include, and which to ignore?
- The laws of thermodynamics are examples of scientific laws. In what ways do scientific laws differ to the laws of human science subjects, such as economics?
- EIAs incorporate baseline studies before a development project is undertaken. To what extent should environmental concerns limit our pursuit of knowledge?
- On what basis might we decide between the judgements of the experts if they disagree?
- What influences your EVS?
- Human impact crosses national boundaries. How can agreement on international environmental issues be reached?
- Can models facilitate international collaboration on environmental issues?



## Quick review

*Each question is worth 1 mark*

**1.** A *system* may best be defined as

**A.** a set of components that function predictably.

**B.** an assemblage of parts and their relationships forming a whole.

**C.** a set of components that function unpredictably.

**D.** an assemblage of functioning parts without inputs or outputs.

**2.** Inputs to a closed system may be

**A.** matter only **C.** matter and energy

**B.** energy only **D.** heat only

**3.** What do outputs from an open system consist of?

**A.** Energy only.

**B.** Matter only.

**C.** Energy and matter.

**D.** Neither energy nor matter.

**4.** A lake with a stream flowing into it, but with water lost only by evaporation, is an example of a system which is

**A.** isolated **C.** unstable and closed

**B.** stable and closed **D.** open

**5.** Which of the following factors would prevent the ecosphere being classified as a *closed system*?

**A.** The input of solar energy.

**B.** The re-radiation to space of heat energy.

**C.** The arrival of rocks as meteorites from space.

**D.** The unstable state of its equilibrium.

**6.** Which statement is correct?

**A.** A lake is an example of an isolated system.

**B.** An open system exchanges energy but not matter with its surroundings.

**C.** The most common systems found on Earth are closed systems.

**D.** A closed system exchanges energy but not matter with its surroundings.

**7.** The carrying capacity of an environment for a given species

**A.** can never be exceeded.

**B.** is greater for a population with a slow reproductive rate.

**C.** is achieved when birth rates equal death rates.

**D.** can only be exceeded with unsustainable use of resources.

**8.** Which of the following conditions would lead to *unsustainable* harvesting of timber from a forest?

**I.** Harvesting trees before they are fully mature.

**II.** Regularly harvesting the full natural income from the forest.

**III.** Reducing mineral content of soil through harvesting.

**A.** I and III only **C.** I and II only

**B.** III only **D.** I, II and III

**9.** *Sustainable yield* can be defined as

**I.** annual growth and recruitment – annual death and emigration.

**II.** (total biomass at time $t + 1$) – (total biomass at time $t$).

**III.** the highest rate at which natural capital can be exploited without reducing its original stock.

**A.** I and II only **C.** II and III only

**B.** I and III only **D.** I, II and III

**10.** Which of the following populations are most likely to be sustainable?

| | Population density | Mean individual consumption | High dependence on |
|---|---|---|---|
| **A.** | high | low | renewable resources |
| **B.** | high | high | renewable resources |
| **C.** | high | high | non-renewable resources |
| **D.** | low | low | non-renewable resources |